GTR

User Manual

Original version

June 2021

Technobis' integrated photonics activities become PhotonFirst

Pioneer with 15 years of experience expands both its proposition and footprint.

Alkmaar, January 1st, 2021 – To enable fast and focused growth, the integrated photonics sensing activities of Technobis have changed their name to PhotonFirst and operate independently from its 'mothership' Technobis Group as of January 1st, 2021.

Thank you for purchasing the GTR1001 product. This manual has been prepared for users of the GTR1001 instrumentation. To ensure correct use, please read this manual carefully before using these products.

- Although every effort has been made to ensure the accuracy of this manual, if you note any points that are unclear or incorrect, contact PhotonFirst.
- Read the instruction manuals for any other products that you are using with this product (a computer or other peripheral equipment).
- If the product is used in a manner not specified by the manufacturer, the protection provided in the product may be impaired.

PhotonFirst Technologies B.V.	
Address	Pyrietstraat 2a 1812 SC Alkmaar The Netherlands +31 85 00 76 700
Email	team@photonfirst.com
Web	www.photonfirst.com
Sales support	team@photonfirst.com
Technical support	support@photonfirst.com
Publication date	June 2021
Document version	7.0
Part number	1001-000
Device type	GTR
HW version, DMR code	2.5/G upwards
SW version	GOS 3.0

1 Referenced documents

Ref.	Document name, source, reference, version, date
[1]	NEN 5509:2016 **source:** NEN; **ref**: NEN 5509:2016; **version:** 2016; **date:** Jan-2016
[2]	DIRECTIVE 2004/108/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC (Text with EEA relevance) **source:** Official Journal of the European Union 31.12.2014
[3]	DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) (Text with EEA relevance) **source:** Official Journal of the European Union 24.7.2012
[4]	DIRECTIVE 2011/65/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) (Text with EEA relevance) **source:** Official Journal of the European Union 1.7.2011
[5]	International vocabulary of metrology – Basic and general concepts and associated terms (VIM) **source:** Joint Committee for Guides in Metrology (JCGM) **version:** 3rd edition **date:** 2008 version with minor corrections Available online: https://jcgm.bipm.org/vim/en/
[6]	NEN-EN-IEC 61300-3-35:2015 Fibre optic interconnecting devices and passive components - Basic test and measurement procedures **source:** NEN; **ref:** 61300-3-35:2015 **version:** 2015 **date:** Nov-2015
[7]	IEC/TR-62627-01:2016 Fibre optic interconnecting devices and passive components - Part 01: Fibre optic connector cleaning methods **source:** NEN; **ref:** IEC/TR-62627-01:2016 **version:** 2016 **date:** Jan-2016

2 Terms, definitions, abbreviations, and conventions

2.1 Terms and definitions

Term or definition	Description
ADAS	Current-to-digital, analogue-to-digital converter
Channel	Optical port on the GTR1001 interrogator to which a sensor array can be attached
Sensor power	The amount power reflected by an FBG sensor over a period
Centre of Gravity value	Weighted Average of the sensor power for a specific sensor
Centre of Gravity wavelength	Centre of Gravity value converted to wavelength based on calibration of the GTR1001 device
Sensor	A single FBG sensor within a sensor array
Sensor array	Fibre sensor containing one or more FBG sensors
Wavelength precision	The random spread of measured values around the average measured values (precision [VIM]) Closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions. The wavelength precision is also referred to as noise
Wavelength measurement range	The measurement wavelength interval (VIM 5.4 see [5]) of the device. Although the wavelength range can differ between devices, the wavelength range in the specifications is the one guaranteed for all devices.
Wavelength repeatability	The measurement precision of a unit under test when measuring under a reproducible set of conditions over a short period of time. (VIM [3.6] see [5]) These conditions include the same measurement procedure, same operators, same measuring system, same operating conditions and same location and a similar unit under test. Wavelength repeatability is also referred to as drift
Wavelength resolution	Smallest change in a quantity being measured that causes a perceptible change in the corresponding indication (VIM 4.14 see [5]). The smallest to be distinguished magnitude of a wavelength value. Resolution of GTR family systems is the minimal Centre of Gravity wavelength step size.
Sensor centre wavelength	The wavelength value where the reflectivity peak of an FBG sensor is located when the sensor is at rest. This is one of the parameters to which an FBG sensor is manufactured.

Term or definition	Description
Sensor dynamic wavelength range	The wavelength measurement range allocated for an FBG sensor in the wavelength range of the device. The extremes of the measurement range are the minimal and maximum wavelength expected for an FBG sensor.
Sensor amplitude dynamic range	The allowed range in peak reflectivity for all FBG sensors interrogated by a device. The range should be valid for the entire dynamic wavelength range allocated to a FBG sensor. The dynamic amplitude range is dependent on the sensitivity setting of a device.
Sensor spacing	The delta between the centre wavelength value of two neighbouring FBG sensors.
Sensor peak reflectivity	Reflectivity of a FBG sensor is its effectiveness in reflecting radiant energy. It is the fraction of incident electromagnetic power that is reflected at an interface. The reflectivity of an FBG sensor is specified for the centre wavelength
Sensor bandwidth	Bandwidth of the FBG sensor where reflected intensity of the FBG sensor is -3 dB of the FBG centre wavelength peak intensity
Side lobe suppression ratio (apodization)	The Side Lobe Suppression Ratio (SLSR) is the ratio of intensity difference between the FBG centre wavelength peak and the biggest side lobe. SLSR is can also be called apodization
Polarization dispersion	FBG writing induced birefringence effect, causing splitting of the FBG spectrum into two polarization axes.
Polarization amplitude dependency	The dependence of the intensity of the FBG centre wavelength peak on the polarization.
Sensitivity setting	Device setting which influences the sensitivity of the device. Depending on the device, the sensitivity settings is applicable for a single or for all channels.
Sample rate	Frequency interval at which the device takes measurements, inverse of the measurement integration time
Differential behaviour of neighbouring sensors	The behaviour of neighbouring sensors in relation to each other. I.e. the expected difference CoG wavelength values in relation to each other.

2.2 Abbreviations

Abbreviation	Meaning
ADC	Analog Digital Converter
API	Application Programming Interface
CoG	Centre of Gravity
CSV	Comma-Separated Values

Abbreviation	Meaning
CTE	Coefficient of Thermal Expansion
FBG	Fibre Bragg Grating
FC/APC(NARROW KEY 2.0 MM)	Fibre Optic Connector for Angled Physical Contact
FWHM	Full Width at Half Maximum
FTDI	Future Technology Devices International
GOS	GTR Operator Software
LED	Light Emitting Diode
SMF	Single mode fibre
SMF 1550	Single Mode Fibre for 1550 nm wavelength
USB	Universal Serial Bus
SLRS	Side Lobe Suppression Ratio
RoHS	Restriction of Hazardous Substances
PMD	Polarization Mode Dispersion

2.3 Reading conventions

This section gives an overview of the stylistic and syntax conventions and their meaning.

DANGER 'DANGER' indicates a dangerous situation which, when the safety instructions are not followed, will result in serious or deadly injuries

WARNING 'WARNING' indicates a dangerous situation which, when the safety instructions are not followed, can result in serious or deadly injuries and/or serious damage to the product or its environment

CAUTION 'CAUTION' indicates a situation which, when the safety instructions are not followed, can result in serious or minor to average injuries and/or damage to the product or its environment

REMARK 'REMARK' highlights important information for the user not related to injuries

3 Table of contents

4 Introduction

This document is written in accordance with NEN 5509:2016 (See [1]) and is the User Manual for the PhotonFirst GTR1001 device.

4.1 Intended Use

The GTR1001 is a high-performance Fibre Bragg Grating (FBG) interrogator, based on state-of-the-art technology such as integrated photonics and low noise electronics. The GTR1001 in this form factor is intended for general use in fibre-optic sensing and testing. Although the internal hardware is capable of withstanding harsh environments, the product in this form factor should be operated in an environment which meets the environmental conditions specified in product specifications (See section 0). Even though the device itself is not capable to withstand harsh environments, the sensor in the attached sensor array can be installed in a harsh operating environment. The GTR1001 in this product form is not qualified for use in regulated markets as medical device or aerospace applications.

4.2 Intended Users

The GTR1001 can be used by any competent user. It is expected that the user is well informed on the use, handling and safety aspects regarding optical fibres and interrogators. A non-exhaustive list of precaution and safety aspects during usage can be found in section 6.

4.3 Product Specifications

Performance properties	
Number of optical channels	1
Channel sampling type	Continuous
Sampling rate	1kHz, 5kHz, 10kHz, default at 19.23kHz
Wavelength measurement range [A]	1516 nm … 1583 nm
Wavelength output resolution	< 1 pm/bit, ≈ 0.275 pm/bit typical
Wavelength repeatability [B]	< 5 pm nominal
Wavelength precision	σ < 2 pm (over 1000 samples at 19.23 kHz)
Power consumption	< 10 W (≈ 5 W at 25°C)
Communication properties	
Data protocol	USB2.0
Output data rate	6,461,280 bits per second @19.230kHz sample rate
Output data unit [C]	Centre of Gravity (CoG) value
Physical properties	
Dimensions [D]	100 mm x 114 mm x 35 mm
Weight	310 grams
Power input (DC)	9 VDC … 36 VDC

Performance properties	
Power adapter input (AC)	80 VAC … 264 VAC (47Hz – 63Hz)
Optical interface	FC/APC(NARROW KEY 2.0 MM), 9/125um compatible single mode fibre (ITU-T G.652D / SMF-28)
Communication interface	USB-B
Environmental properties	
Operating temperature range	0°C … 45°C
Storage temperature range	-20°C … 75°C
Degree of protection	IP20
Sensor array properties	
Max number of FBG per channel	8
Minimum sensor spacing [E]	5.1 nm
[A] Wavelength range guaranteed for all GTR devices, typical range is 1515 nm … 1585 nm.	
[B] Repeatability defined as the nominal average wavelength drift over a period of 20 minutes, in a steady state environment. Maximum allowed wavelength drift <30pm. Contact PhotonFirst for extensive repeatability and reproducibility information.	
[C] Refer to Annex B	
[D] Including FC/APC(NARROW KEY 2.0 MM) coupler and rubber feet.	
[E] Typical minimum spacing 4.8 nm. [Refer to FBG definition]	

Table 1: Product specifications

4.4 Product Identification

The product is uniquely identified by its serial number. The serial number contains all required META data to trace back the products origin. The serial number composition is described in the following table.

Description	Specification
Format	TTYYMMCXX
TT	Model/type code
YY	Year of manufacturing (i.e. 16 = 2016, 20 = 2020, etc.)
MM	Month of manufacturing (01 … 12)
C	HW version, DMR code (i.e. E = DMR 2.3)
XXX	Unique Numeric Identifier (001 … 999)

Table 4-1: Serial number composition

The serial number is located on the product label on the bottom of the product (see 5.4.2.4).

4.5 Sensor array specifications

This section gives both the specifications / requirements for sensor arrays used in combination with a GTR device as a rationale for these specifications to maximize your sensing system's potential.

Description	Specification
FBG sensor Reflectivity*	R = 0.5 – 0.99 (50% – 99%)
Detected FBG sensor FWHM*	100 pm – 500pm
Operational FBG sensor FWHM	250pm – 300 pm
Minimal Sensor spacing**	5.1 nm
Sensor array fibre type	9/125um compatible single mode fibre (ITU-T G.652D / SMF-28)
Sensor array polarization dispersion	< 5 pm
Side modes suppression (apodization)	> 15 dB, or < -15 dB
Sensor array connector type Sensor array termination	FC/APC(NARROW KEY 2.0 MM) connector 8-degree angle (< -20 dB reflection) or FC/APC(NARROW KEY 2.0 MM) connector
* Sensors with a Reflectivity/FWHM outside the operational sensor specifications will cause the GTR to operate out of specifications.	
** Typical minimum spacing 4.8 nm	

Table 4-2: Sensor specifications

All FBG sensor specifications expect that the extremes of the dynamic range are considered. Example: for an FBG sensor with centre wavelength 1518 nm and a dynamic range of 2 nm, the dynamic range extremes are 1517 nm and 1519 nm. Other FBG specifications might work, but specifications are not guaranteed. For example, sensitivity levels can be customized in settings to work for low reflectivity FBGs (but not different for individual optical channels). In case of doubt please contact Photonfirst for support in choosing a suitable range and FBG configuration.

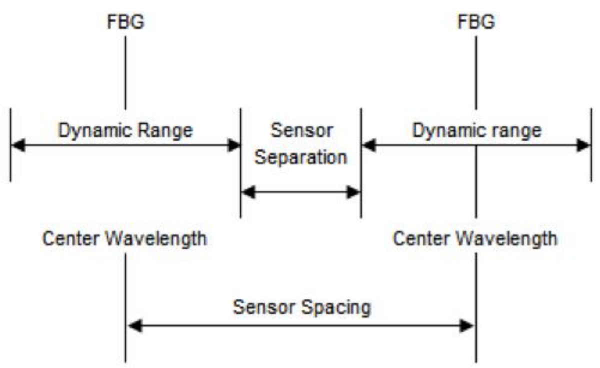


Figure 4-1: Depiction of the terminology in sensor array specifications as used by Photonfirst.

4.5.1 Sensor dynamic range

The dynamic range of a sensor in a sensor array is dependent on the number of sensors in a sensor array. Table 4-3 gives an overview of the typical dynamic range based on the number of sensors. This table assumes full usage of the nominal[1] operational wavelength range of a GTR device (1515 nm – 1585 nm) and does not take the physical limitations of fibre arrays in account.

# Sensors	Max dynamic range [nm]	Max temperature range [K]	Max strain range [με]
8	3.95	395	3291
7	5.2	520	4333
6	6.8	686	5722
5	9.2	920	7666
4	12.7	1270	10583
3	18.5	1853	15444
2	30.2	3020	25166
1	65.2	6520	54333

Table 4-3 Theoretical maximum sensor dynamic range for a GTR system not taking physical limitation of FBG sensors, sensor arrays into account using the typical operational wavelength range of a GTR device

4.5.2 Sensor array termination

To prevent back reflection from polluting the measurements, sensor arrays need to be terminated in a way there is no back reflection from the end facet.

This can be done by:

- Specifying the fibre needs to be terminated at an 8 degrees angle when ordering the fibre / sensor array (< -20dB reflection)
- Using an angled connector at the end of the fibre / sensor array
- Cutting the fibre/sensor array at an angle using a knife (quick and dirty)
- To verify the back reflection in a fibre, check the overall offset present across the whole spectrum.

[1] The operational wavelength range may vary slightly per device due to manufacturing variations. Consult Photonfirst for more information.

5 Product description

5.1 GTR Measurement Concept

The basic optical sensing concept of a GTR system (how a GTR measures a sensor array), is depicted in Figure 5-1. A spectrally broadband light source (Super luminescent diode or SLED) is illuminating a sensor array. The light reflected by the FBG sensors is measured by the interrogator (a Photonic Integrated Chip or PIC) in the GTR device. Because each sensor in a sensor array reflects light at a different wavelength, it is possible to measure all the sensors in a sensor array simultaneously.

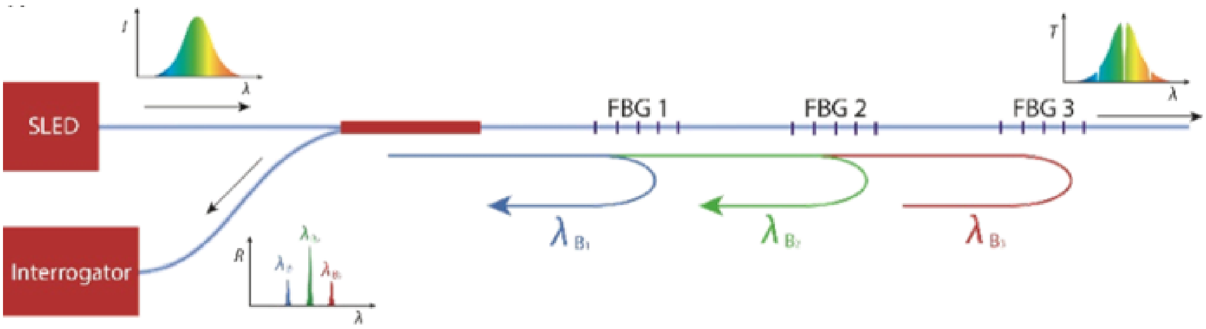


Figure 5-1 Measurement concept how a GTR system measures a sensor array

The interrogator PIC is a spectrometer which integrates the spectrum reflected by the sensor array over 48 pixels at the GTR sample rate. An example of the representation of pixel values can be found in Figure 5-2.

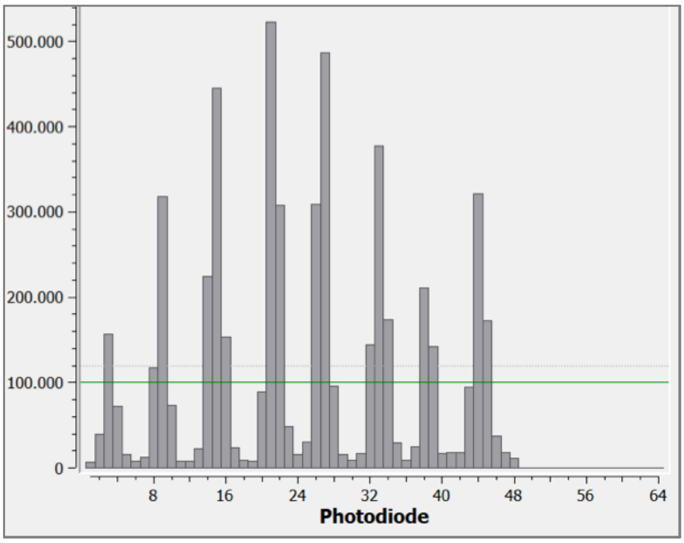


Figure 5-2 Pixel representation of a sensor array by a GTR system.

The representation of the reflected spectrum is interpreted by the GTR internal logic. The logic uses three pixels per FBG sensor to determine its CoG value.

5.2 GTR Usage

This section covers the standard type of usage of the GTR product.

On a high level these types of usage are:

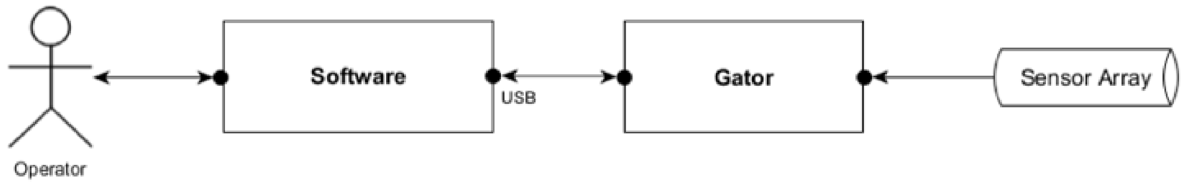
- Interactive; measurement data is used by an operator
- Automatic logging: measured data is stored in a log, usually for monitoring postponed analysis
- Automatic control input: measured data is used by a control process

The data in the output stream of the GTR is in CoG.

Conversion to strain and/or temperature is implemented in the GOS and described in section B.1.

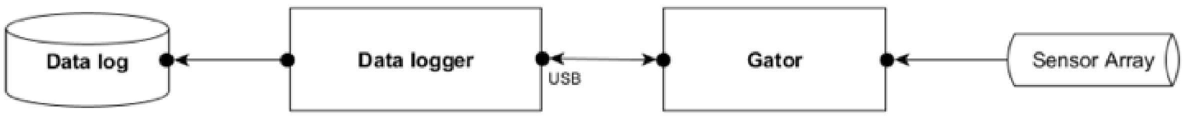
5.2.1 Interactive usage

The GTR is connected to a computer via USB and the data is streamed to and interpreted by software. The software can be either the GTR Operator Software (see section 10.6), third party software with a plugin (e.g. LabVIEW, MATLAB), or a custom program which interprets the output stream using FTDI API (see section Appendix A for the protocol) or the GTR Operator API. The GTR Operator Software is used to change GTR parameters.



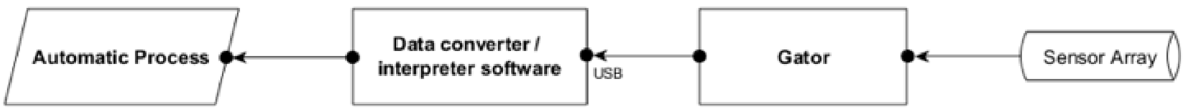
5.2.2 Automatic logging usage

The GTR is connected to a data logger. The data logger is software or hardware which converts the output data to a format logged in a data log. The GTR Operator Software can function as a data logger, it is also possible to use custom software/hardware.



5.2.3 Automatic control loop usage

If the GTR output is used as input for an automatic process, data converter/interpreter software is used to convert the GTR output to an input recognized by the external process. The GTR Operator Software does not have this ability. For such application additional software needs to be developed, either by the customer or by PhotonFirst.



5.3 Software

5.3.1 Purpose

The purpose of the GTR Operator Software (GOS) is to control the GTR and to read and process the output data.

5.3.2 Description

The GTR1001 product is delivered with the GOS. GOS provides in:

- Visualization of the sensor status and values
- The ability to save GTR output data to a (CSV) file (see section 10.6.3)
- The ability to change a limited number of firmware settings (when supported by your GTR firmware) (see section 10.3)
- The ability to save images of the graphs in the application (see section 10.3)

The GTR Operator Software offers basic usage of the GTR1001.

Please contact team@photonfirst.com for more information on custom software development.

REMARK The conversion to units other than wavelength or CoG are dependent on sensor installation and the application. The GOS conversion formulas to strain and temperature are described in section Appendix B. The formulas are linear. Custom software development is required for non-linear conversion routines.

5.4 GTR1001 Overview

5.4.1 Purpose

The purpose of the GTR1001 is to interrogate FBG sensors. Intrinsically it provides strain and/or temperature measurement capability. Depending on the sensor installation and application it allows for extrinsic measurement capabilities like pressure, shape, humidity, etc.

5.4.2 Description

5.4.2.1 Front panel indicators and connectors

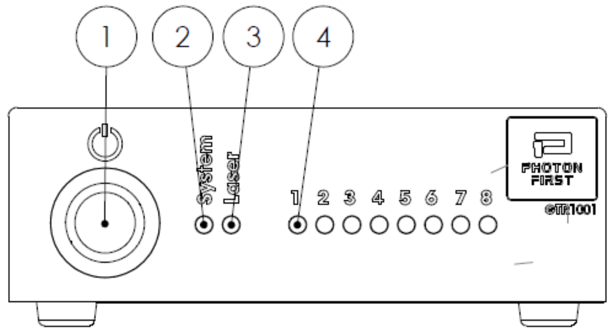


Figure 5-3 GTR1001front panel

① **Power Button**
Used to turn the interrogator device on and off. The power status is indicated by the LED embedded in the power button. See Table 5-1 for more information on the indications given by the power LED.

LED indication	Status LED indications
Off	System is powered off
On	The system is turned on

Table 5-1 Power LED status indication (Red LED embedded in power button) ①

② **GTR System Status LED**
An orange LED indicating the status of the GTR1001. See Table 5-2 GTR1001 System Status LED indications (orange LED ②) for more information on the indications given by the System Status LED.

LED indication	System Status LED indications
On	System is functioning correctly and within specs
Blinking 2 times per second	Internal temperature stability not ok or electronics temperature not in range.
Blinking 4 times per second	General system error. A GTR system will not recover from this error without a power reset.

Table 5-2 GTR1001 System Status LED indications (orange LED ②)

③ GTR light source LED

A blue LED indicating the status of the internal light source . See Table 5-3 for more information on the indications given by the light source LED.

LED indication	Status LED indications
Off	Light source is off (not provided with power)

Table 5-3 GTR1001 Laser indications (blue LED ③)

④ GTR Sensor Status LEDs

Green numbered LEDs indicating the status of the sensors detected by the GTR1001 System. There are 8 Senor Status LEDs, each indicating the Status of one of the maximum 8 sensors in the attached FBG sensor fibre. See Table 5-4 GTR1001 Sensor status (green LEDs ④) for more information on the indications given by the Sensor LEDs.

LED mode	Status LED indications
Single sensor LED off	Sensor not detected or sensor signal level too low
Single sensor LED on	Sensor detected and working properly
Single sensor LED blinking 1 times per second	Sensor detected; signal amplitude (level) too high (saturated). See section 10.6.4 item 3 how a GTR1001 can be configured to resolve this error.
One sensor blinking 4 times per second	Sensor detected; signal is out of range, i.e. the signal is just outside the wavelength measurement range.
Two sensor LEDs blinking 2 times per second	The sensors signals are too close together, i.e. the spectral spacing between the signals is too small.

Table 5-4 GTR1001 Sensor status (green LEDs ④)

5.4.2.2 Back Panel indicators and connectors

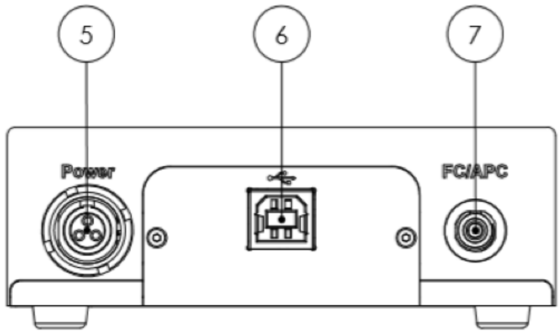


Figure 5-4 GTR1001 back panel

⑤ **Power plug connector**
To be used with the power adapter supplied with the system by PhotonFirst.

REMARK The power connector is a locked push pull connector.

⑥ **USB 2.0 Connection**
Connection used for data transfer to a host system. This connection is used for both data transfer and control. See Appendix A for details on the data protocol, see section 10.2.4 for details on GTR1001 configuration.

⑦ **FC/APC(NARROW KEY 2.0 MM) Connection**
The connection to which the FBG sensor fibre should be attached. See section 8.1.

REMARK Always leave the dust protection cap on when no fibre is connected. Dust and dirt can reduce optical transmission and permanently damage the fibre facet.

5.4.2.3 Cable connectors

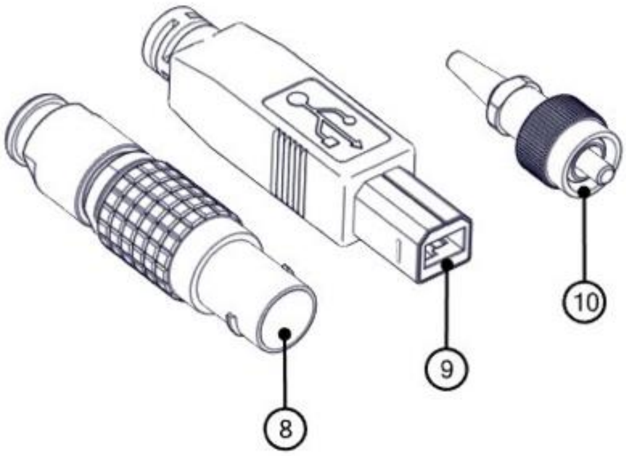


Figure 5-5 GTR1001 connectors

⑧ **Power connector**

Power connector attached to the power adapter supplied with system.

REMARK To disconnect the power connector, pull back the knurled part to release the connector.

⑨ **USB connector**

The USB cable is supplied with the system.

⑩ **Sensor array connector**

Sensor array with FC/APC(NARROW KEY 2.0 MM)(Narrow Key 2.0 mm) connector. In Appendix D the sensor fibre order information template is described.

5.4.2.4 GTR1001 exterior symbols

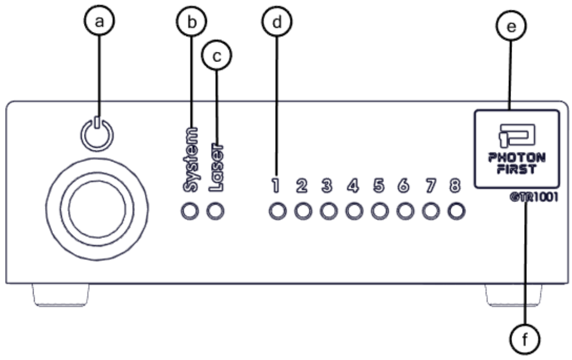


Figure 5-6 Symbols used on front panel of GTR1001

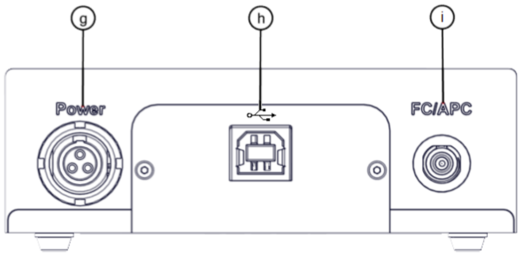


Figure 5-7 Symbols used on rear panel of GTR1001

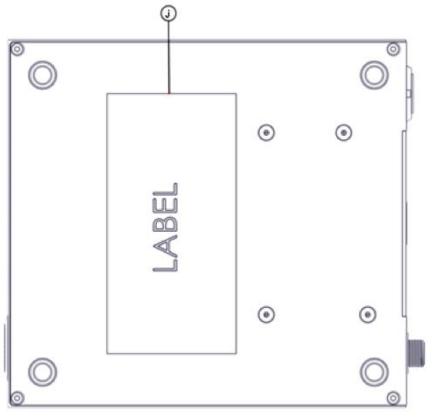


Figure 5-8 Symbols used on bottom panel Type Label of GTR1001

ⓐ **Power On/Off logo**
ⓑ **System indicator LED**
ⓒ **Light source indicator LED**
ⓓ **Sensor number LED**
ⓔ **PhotonFirst logo**
ⓕ **Product name**
ⓖ **Power connection**
ⓗ **USB connection**
ⓘ **Sensor array FC/APC(NARROW KEY 2.0 MM) connection**
ⓙ **Label with contact information, product name, serial number, manufacture date, input rating, CE directive compliance, Class 1 Laser Product warning and PhotonFirst logo**

REMARK A warranty sticker is placed over a screw on the bottom of the GTR1001 system. Removing, damaging, or modifying the warranty sticker will result in a warranty void.

6 Precautions and safety instruction

The product has been designed with safety in mind and should be used with common sense. Safety may be compromised in case The GTR usage is not in accordance with the instructions given in this document. The major safety instructions are given in the sections below.

6.1 Laser safety

The GTR1001 product comprises a broadband infrared light source, which is invisible to the human eye. Although intrinsically safe (Class 1, $P_{out} < 10$ mW), it is advised not to look in the fibre-optic connections or the exit facet of a connected fibre.

The GTR1001 product is intended for use in fibre-optic systems solely, i.e. intended for FBG sensing. It should not be used in combination with other types of sensing equipment, fibre-optic telecommunication networks or any other equipment besides the equipment provided or advised by PhotonFirst.

WARNING Do not look directly or indirectly in the fibre-optic connections when the laser (③) is on.

6.2 Electrical safety

This product has been tested, validated, and qualified with the power adapter provided.

CAUTION Do not use any other means of power supply or other type of power adapter in combination with the GTR1001 than provided with the system.

6.3 Electromagnetic safety

This product has a CE certificate (see Appendix E) and been tested against the EU Directive 2014/30/EU for EMC. Product performance and functioning are not guaranteed when used in electromagnetically environments harsher as specified in the directive.

REMARK When measuring in harsh electromagnetic environments it is best to place the product outside the environment and have a sensor array with enough lead length to measure inside the environment.

6.4 Optical instructions

WARNING Both sides of an optical connection should always be visually inspected and cleaned according to the cleaning instructions given in section12 before making a connection

WARNING Only remove protective dust cap in clean environments and as short and as few times as possible. Dirt particles can damage the optical end face. (Section 11)

WARNING Only use the sensor arrays with FC/APC(NARROW KEY 2.0 MM) (narrow key) connectors compliant with the specifications provided by PhotonFirst. PhotonFirst is not liable for inappropriate use.

CAUTION Make sure the power is off when making optical connections.

6.5 Other instructions

WARNING The product is not designed for outdoor use. To avoid the possibility of injury, do not expose the product to rain or excessive moisture, nor operate it in the presence of flammable gases or fumes.

WARNING The user is strongly advised against opening, repairing or modifying any of the delivered products or its components. If the user is inclined towards opening the GTR1001 system, please contact PhotonFirst for support.

WARNING Do not put anything on top of the device housing. This will reduce the cooling capacity of the device and may lead to performance outside of specification.

6.6 Disposal of Waste Equipment (WEEE)

The European Union WEEE (Waste Electrical and Electronic Equipment) Directive 2012/19/EU (see Appendix E) of 2014 states that electrical and electronic waste must be separately collected for the proper treatment and recovery to ensure that WEEE is reused or recycled safely.

This product is marked with the symbol shown below, indicating that one must not discard the product with unsorted municipal waste. Please contact your local representative for disposal in accordance with local law or PhotonFirst for further instructions on waste handling.

7 Transport and storage instructions

7.1 Transport

The GTR1001 and its accessories are shipped inside a dedicated case (see Figure 7-1). During transportation, all connectors should be disconnected and covered with the supplied caps if applicable. The total weight of the case including its content is 1600 grams.

7.2 GTR1001 delivery contents

7.2.1 Contents of GTR1001 transportation box

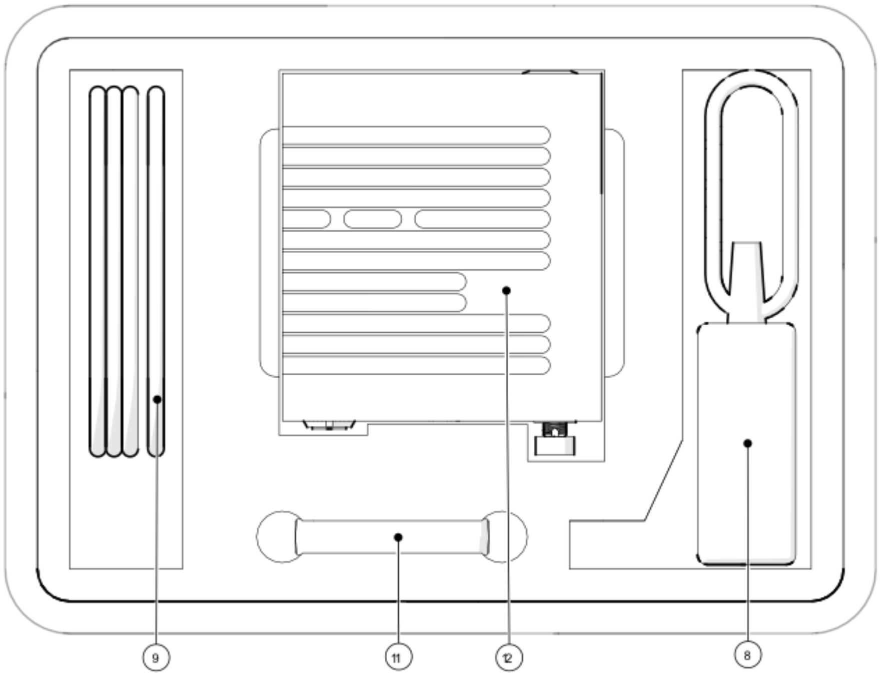


Figure 7-1 GTR1001 case layout

⑧ **Power supply**
⑨ **USB cable**
⑪ **USB flash drive**
⑫ **GTR1001**

Also included: Fibre cleaning instruction.

7.2.2 USB flash drive contents

The GTR1001 is delivered with a USB flash drive containing:

- The GTR User Manual (this document) in pdf format
- Installer for the GTR Operator Software, which includes the FTDI USB driver.
- Fibre cleaning one pager in pdf format

7.3 Storage

The GTR1001 should be stored under the following conditions:

Description	Specification
Storage Temperature range	-20°C … +75 °C
Degree of Protection	IP 20 (EN/IEC 60529)

Table 7-1: Storage specifications

8 Installation instructions

All necessary hardware (excluding the sensor array) and software is supplied within the GTR1001 transportation case as indicated in section 7.2.1.

8.1 Hardware Installation

WARNING The device should be installed in accordance with the safety instructions given in section 6.

This section contains references to section 5.4.2.1 until 5.4.2.3.

1. Connect the power plug ⑧ to the GTR1001 power connector ⑤.

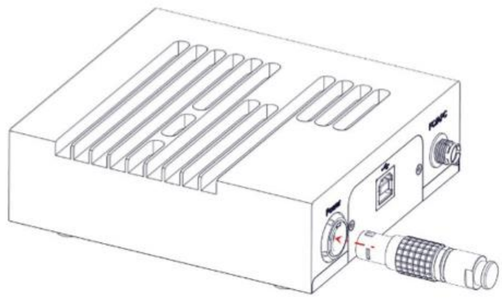


Figure 8-1 Connecting power plug

WARNING Only use the power adapter supplied with the GTR1001.

2. Connect the USB connector ⑨ to the GTR1001 USB connector ⑥. Use the USB cable (USB 2.0 AB patch cord) provided with the system.

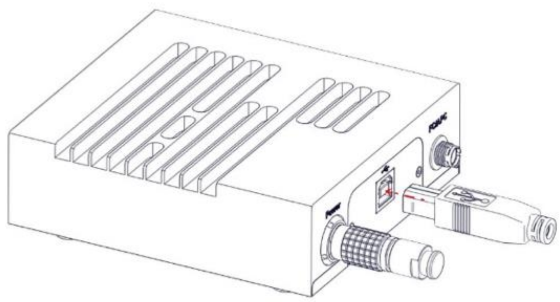


Figure 8-2 Connecting USB cable

REMARK Connect the USB cable supplied with the GTR1001 directly to the host device. Interference of third-party peripheral equipment – such as a USB-hub – may lead to performance outside of specification.

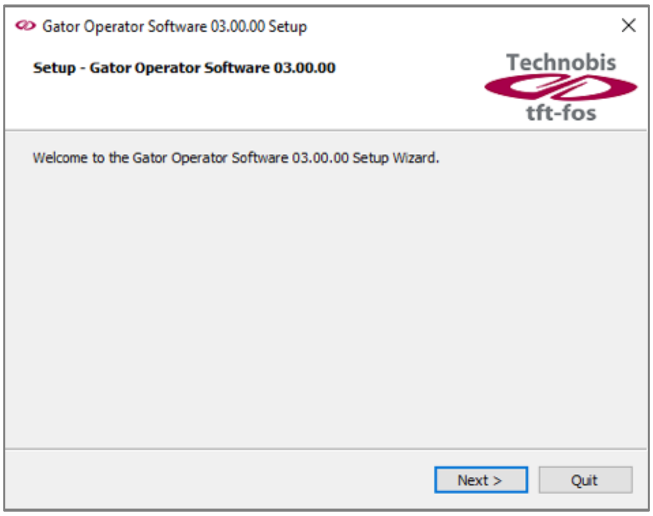
8.2 Software Installation

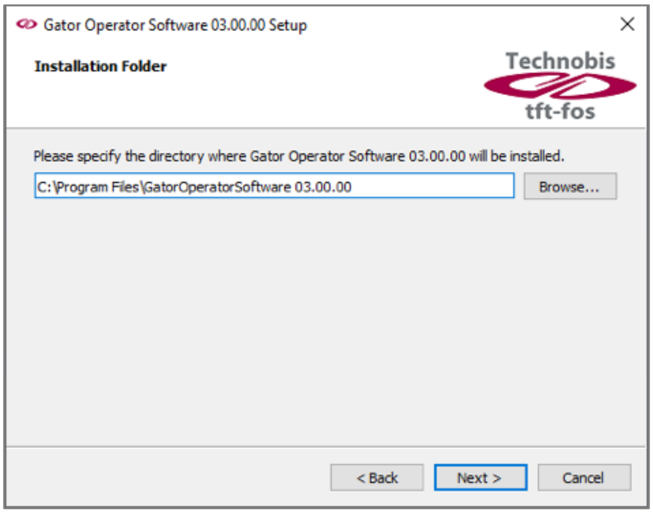
The GTR Software is delivered with the GTR1001 on a USB flash drive. This section gives description how the software should be installed.

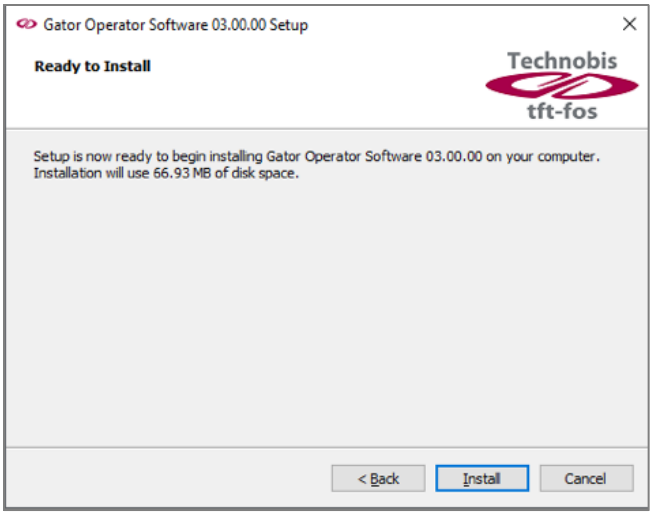
1. Start the installer found on the USB flash drive (GatorOperatorSoftware_32bit_installer_xx.yy.zz.exe)

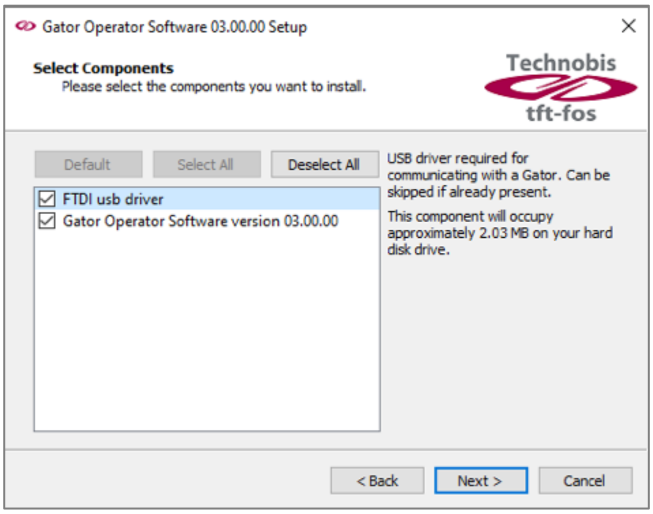
2. Follow the instructions in the installation wizard

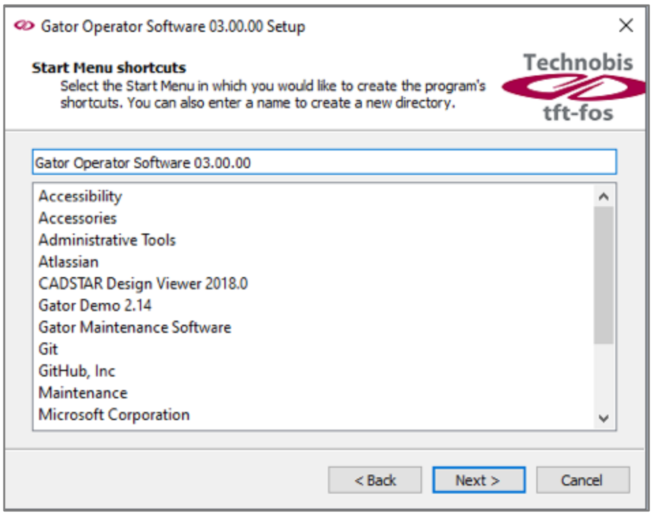
REMARK Deselect the FTDI USB driver component in case already installed on the system.

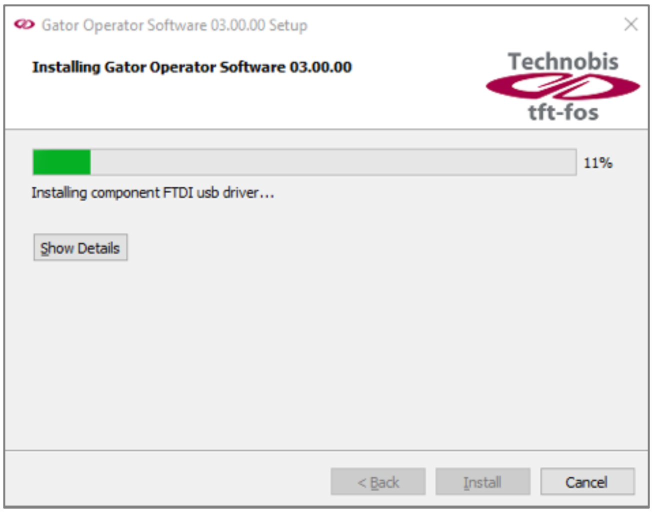




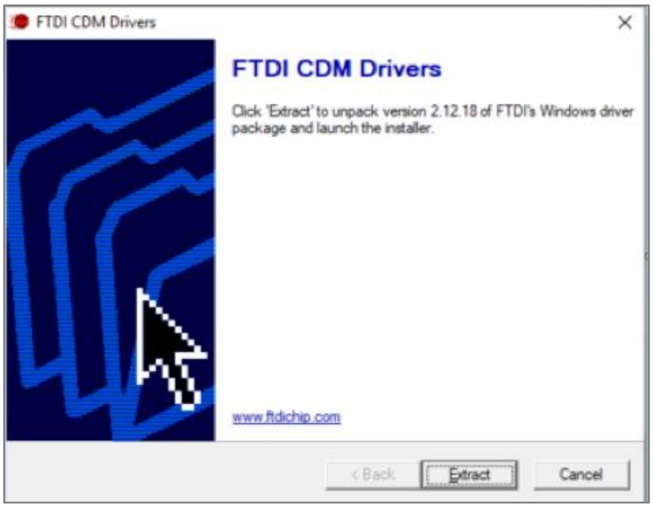

Gator Operator Software 03.00.00 Setup
Ready to Install
Technobis
tft-fos
Setup is now ready to begin installing Gator Operator Software 03.00.00 on your computer.
Installation will use 66.93 MB of disk space.
< Back
Install
Cancel

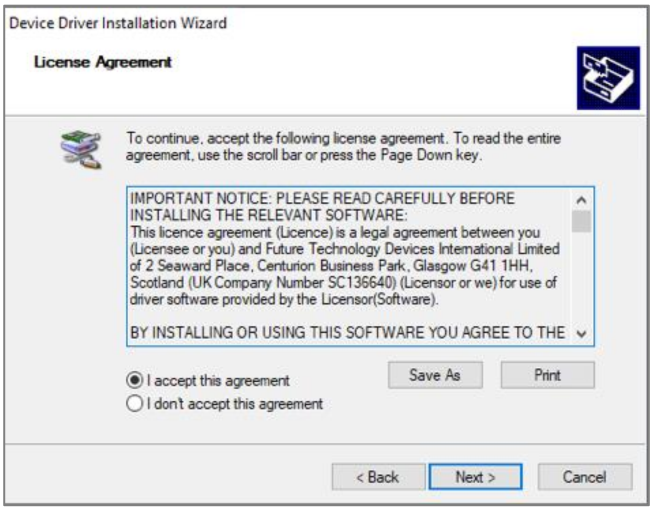

Gator Operator Software 03.00.00 Setup
Select Components
Please select the components you want to install.
Technobis
tft-fos
Default
Select All
Deselect All
FTDI usb driver
Gator Operator Software version 03.00.00
USB driver required for communicating with a Gator. Can be skipped if already present.
This component will occupy approximately 2.03 MB on your hard disk drive.
< Back
Next >
Cancel

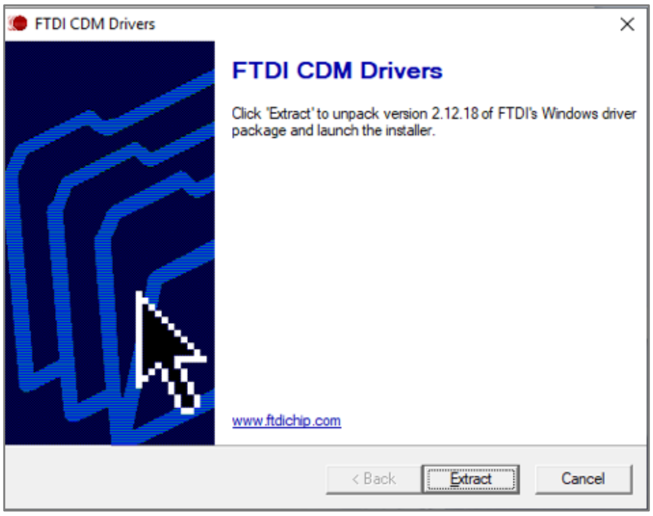

Gator Operator Software 03.00.00 Setup
Start Menu shortcuts
Select the Start Menu in which you would like to create the program's shortcuts. You can also enter a name to create a new directory.
Technobis
tft-fos
Gator Operator Software 03.00.00
Accessibility
Accessories
Administrative Tools
Atlassian
CADSTAR Design Viewer 2018.0
Gator Demo 2.14
Gator Maintenance Software
Git
GitHub, Inc
Maintenance
Microsoft Corporation
< Back
Next >
Cancel



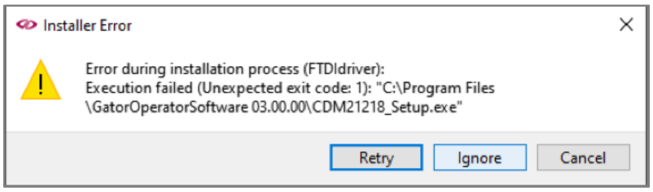
3. If selected, follow the installation instruction for the FTDI driver



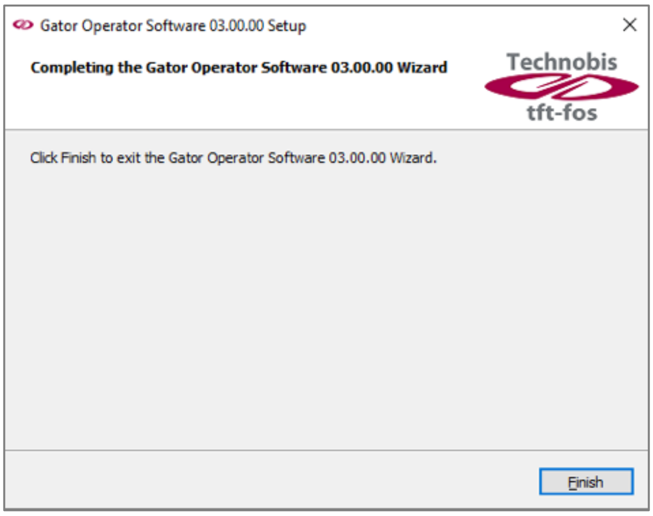




REMARK In case the FTDI driver is already present on the system, the following error can be ignored.



4. Wait until the GTR Operator Software is installed and click finish.



Once the installation is finished, the Windows Start menu will contain two new short-cuts (located by default in the GTR Operator Software folder in Start menu).

- Gator Operator Software xx.yy.zz; short-cut to the GTR Operator Software executable (see section 10.1).
- Uninstall Gator Operator Software xx.yy.zz ; short-cut for de-installing GTR Operator Software.

9 Commissioning

9.1 Fibre sensor array installation

1. Make sure the device is turned off
2. Remove protective cap from FC/APC(NARROW KEY 2.0 MM) connector ⑦

CAUTION When powered do not look directly into the fibre-optic connector.

CAUTION Only remove protective cap in clean environments to ensure cleanliness of the connector. (Section12)

3. Make sure that the GTR connector ⑦ and the sensor array connector ⑩ are clean with each use as induced damage can be permanent to both facets (not covered by warranty). See section 12 for cleaning and inspection instructions.
4. Connect the fibre with FC/APC(NARROW KEY 2.0 MM) connector to the GTR. Align the sensor tab with the slot of the FC/APC(NARROW KEY 2.0 MM) connector. Turn the screw cap on the connector's thread to lock the sensor.
5. Turn on the device.
6. Connect the GTR to a computer and start the GTR Operator Software.
7. Use firmware settings screen to set the F-factor and threshold in case required. (see 10.3 and 10.6.4.2)

Once the sensor fibre is correctly attached, the system automatically determines the number of sensors connected and the sensor status (see section 5.4.2.1). For specifications of the recommended FBG sensors, see section Appendix D.

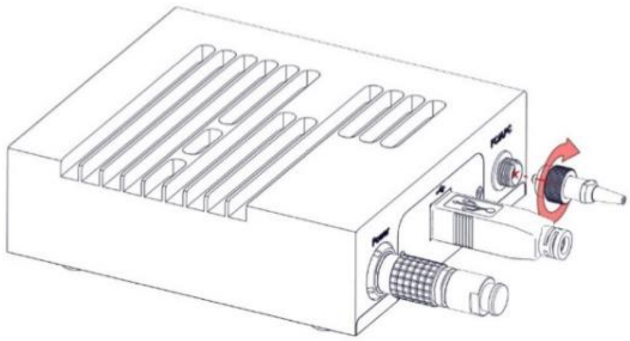


Figure 9-1 Connecting FC/APC(NARROW KEY 2.0 MM) sensor array connector

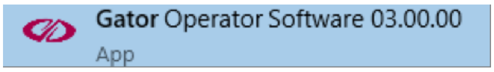
10 Operating instructions

The GTR Operator Software (GOS) is the standard control software delivered with the GTR1001. The GOS installer is located on the USB flash drive; the installation instruction can be found in section 8.2.

10.1 Starting

After installation, the start menu should contain a shortcut named "Gator Operator Software xx.yy.zz".

Use this icon to start the program:



Before starting the software, the GTR should be connected via USB and switched on to identify the system. For optimal performance, a warmup time of 20 minutes is advised.

NOTE: The user should not start the software GOS before the system is stabilized, indicated by a constant orange led

10.2 Application screen

The GOS application screen is shown in the figure below. Details on the application components identified in the figure are explained in the subsections of this section.

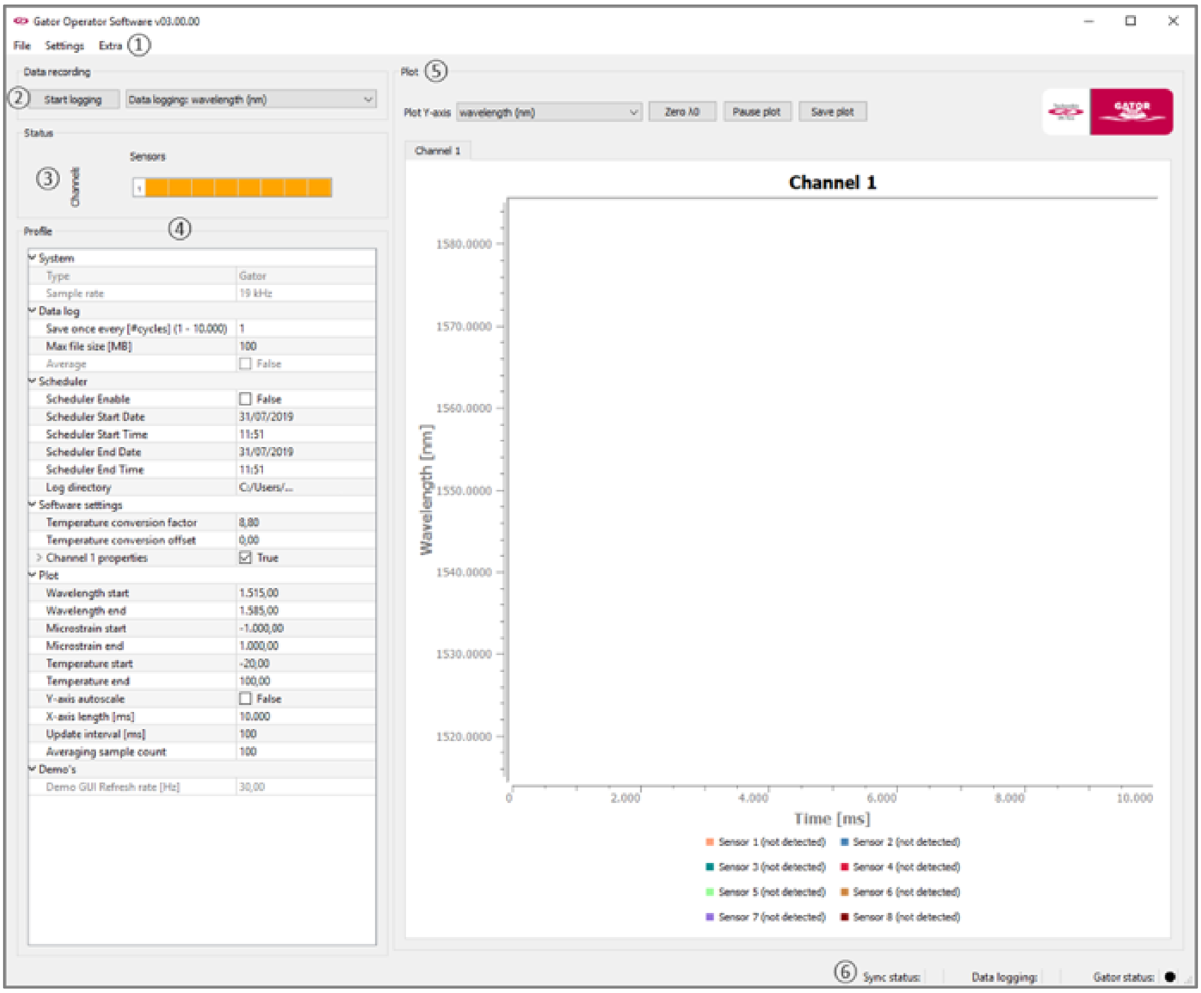


Figure 10-1 The GOS application screen, numbers indicate the different sections of the screen which are described later in this section

- ① **Application menu (see 10.2.1)**
- ② **Recording controls (see 10.2.2)**
- ③ **Sensor status group (see 10.2.3)**
- ④ **Application profile (see 10.2.4)**
- ⑤ **Plot group (see 10.2.5)**
- ⑥ **Connection status (see 10.2.6)**

10.2.1 Application menu

The application menu options are listed below:

Menu	Menu item	Description
File	Save default profile	Save the current profile as default profile
File	Load profile from file	Load a stored profile from file
File	Save profile to file	Save the current profile to a different file
File	Exit	Exit GOS
Settings	Firmware	Inspect and change firmware settings
Extra	Surface demo	Photonfirst demonstration application
Extra	Surface demo with A330 model	Photonfirst demonstration application
Extra	Surface demo with a helicopter	Photonfirst demonstration application
Extra	Skopinski sensor calibration model	Photonfirst demonstration application
Extra	High-speed shape capture	Photonfirst demonstration application
Extra	All demos combined	Photonfirst demonstration application

Table 10-1 Menu options for Application menu indicated as ① in Figure 10-1.

10.2.2 Recording controls

The recording controls contain the main control interfaces for starting data logging of data received from the GTR to a file. This section gives a description of the controls in the group. Details on how logging can be configured are described in section 0.

- "Start logging" / "Stop logging" button. This button is used to manually start or stop logging data to a file. On start a popup appears for data storage filename location. Pressing the button again will stop logging and closes the datafile.
- The Data logging: dropdown can be used to select the data storage unit. See section 0 for details on the units and conversion routines.

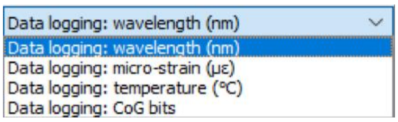


Figure 10-2 Data logging dropdown menu

10.2.3 Sensor status group

The sensor status group contains 8 coloured status indicators, one for each sensor in the connected sensor array.

- An orange indicator indicates no sensor detected
- A green indicator indicates sensor detected
- A red indicator indicates a sensor error
- A purple indicator indicates no (extra) FBG expected, but observed

10.2.4 Application profile

The application profile displays settings of the GTR, including plot configuration and data logging options. Table 10-2 depicts an overview of the groups in the profile and, if applicable, a reference to the section detailing how to use the items in the groups.

Group	Description	Reference
System	(Read-only) GTR settings, Type: System type of GTR Sampling rate: Sampling rate of the GTR	-
Data log	Settings for data logging	Section 0
Scheduler	Settings for scheduling automatic data logging	Section 0
Software settings	Turning channels on/off, Temperature conversion factor	Section 10.2.4.2
Plot	Plot settings	Section 0
Demo's	(Read-only) Settings used for the demo applications Refresh rate: Update frequency of the demo screen	
Group	Description	Reference

Table 10-2 Application profile sections (4 in Figure 10-1)

Data logging

Plot profile setting	Description
Save once every [#cycles]	Logging interval cycles (Use this option to reduce the log size)
Max file size	The maximum size of a log file
Average	Checkbox used to indicate data storage mode: Average over n cycles (true) or Ignore each n cycles (false).

Table 10-3 Data logging settings found in Application profile section (④ in Figure 10-1)

10.2.4.1 Scheduler

Plot profile setting	Description
Scheduler enable	Schedule data logging
Start date	Start date of the automatic scheduled logging
Start time	Start time of the automatic scheduled logging
End date	End date of the automatic scheduled logging
End time	End time of the automatic scheduled logging
Log directory	Directory where the scheduled files will be saved.

Table 10-4 Scheduler settings found in Application profile section (④ in Figure 10-1)

10.2.4.2 Software settings

Plot profile setting	Description
Temperature conversion factor	See Appendix 0
Temperature conversion offset	See section 10.5
Channel properties	To change multiple channel properties
Enable/disable logging of channel *n*	Note: The GTR1001 has only one channel. Disabling channel 1 logging will result in an empty log
Channel Label	Changes the channel name of the ADAS Chart and tabs in the plot section
Sensor Log Count	To enable/disable count for selected sensors
Channel Unit	Dropdown menu to set the unit of measurement
Label sensor *n*	Changes the name of the selected sensor, will display at the bottom of the ADAS Chart
Central wavelength (λ0) sensor *n*	To set central wavelength for the selected channel.

Table 10-5 Software settings found in Application profile section (④ in Figure 10-1)

Plot settings

Plot setting	Description
Wavelength start	Lower value on the Y-axis when plotting wavelengths when autoscaling is off
Wavelength end	Upper value on the Y-axis when plotting wavelengths when autoscaling is off
Micro-strain start	Lower value on the Y-axis when plotting strain when autoscaling is off
Micro-strain end	Upper value on the Y-axis when plotting strain when autoscaling is off
Temperature start	Lower value on the Y-axis when plotting temperature when autoscaling is off
Temperature end	Upper value on the Y-axis when plotting temperature when autoscaling is off
Y-axis auto scale	Checkbox for selecting if autoscaling should be on or off
X-axis length [ms]	Timescale on the X-axis how long data should be plot. I.e. how long should the history of the plot be.
Update interval [ms]	Refresh Rate of the X-axis, Time
Averaging sample count	Sample per pixel on the plot measurement line.

Table 10-6 Plot screen settings found in Application profile section (4 in Figure 10-1)

10.2.5 Plot group

The plot group contains the main controls for the plot showing the measured values received from the GTR. Details on how to configure a plot can be found in section 10.6.1, this section only gives an overview of the controls.

- Plot Y-axis: Drop-down to determine the unit used in plot (see section 0)
- "Zero λ0; Button which sets the central wavelength (λ0) of the detected sensors to the current value
- "Pause plot"/ "Continue plot" button; Button which can be used to pause or continue plotting the live data received from the GTR
- "Save plot" button; Save the current plot as a figure to a file

10.2.6 Connection status

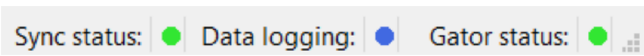


Figure 10-3 Connection status indicators

This group contains three indicators:

- Sync status, Green indicator if the GTR1001 is synced (only when hardware allows)
- Data logging, Blue blinking indicator if the GTR1001 data is being logged to file
- GTR status, Green indicator if the GTR1001 is connected

10.3 Firmware setting screen

The firmware configuration screen is accessible via the Settings->Firmware option in the main menu and is only available when the hardware configuration allows modifying settings of the GTR. The firmware configuration screen is shown in the screenshot below. Details of the identified controls and settings can be found in the table below the figure.

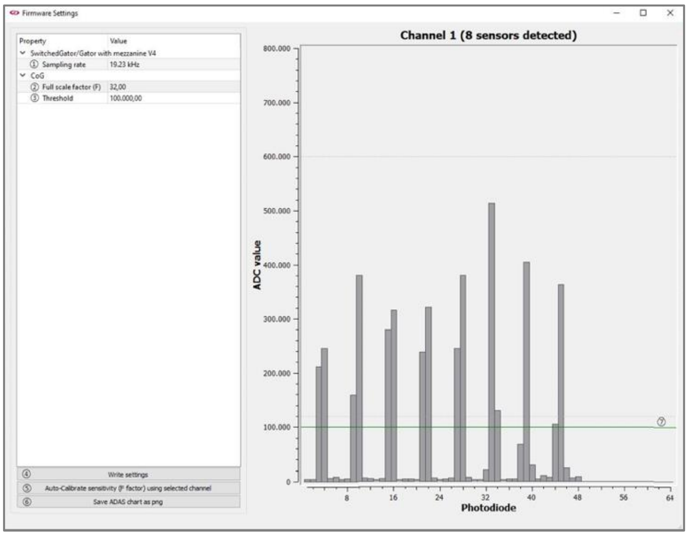


Figure 10-4 GTR Firmware settings screen in which GTR1001 settings can be changed

Id	Name	Description
①	Sampling rate	Dropdown menu for setting the sampling rate of the GTR
②	Full scale factor (F)	Gain factor of the ADC used in the GTR
③	Threshold	Threshold value above which the GTR should detect a sensor
④	Write settings	Button for writing new settings to the GTR1001
⑤	Auto-calibrate sensitivity (F-factor)	Auto-calibrate the ADC gain factor
⑥	Save ADAS chart in PNG image format	Save the current ADAS chart to a *.PNG file
⑦	Threshold line	Line at which the threshold is set.

Table 10-7 Explanation of items indicated in Figure 10-4

10.4 Data logging format

The logged data of the GTR Operator Software is written to a CSV file with the following fields:

#	Field name	Description
0	GOS timestamp	Timestamp the packet was received by the GTR Operator Software. Format: <ddmmmyyyyTHHMMss> for example 12Oct2019T120812 is 12 October 2019 12:08:12
1	GTR Timestamp	Internal timestamp in micro-seconds in the GTR system when the package was created. Timestamping is reset at GTR initialization.
2	Sequence number	Package sequence number from the interrogator package used to make this entry.
3	GTR Status	GTR status from the interrogator package used to make this entry
4	GTR TEC Status	GTR TEC status from the interrogator package used to make this entry
5	GTR Missed packets	Counter how many data packets where missed by the software
6	Channel number	Channel number for which the sensor data is given (always 1 for a GTR1001)
7	Number of detected sensors	The number of sensors detected from the GTR package used to make this entry
8	Sensor 1 value	Sensor 1 data value; Average value in case averaging is on. Value is 0 when sensor is not detected.
9	Sensor 2 value	Similar to Sensor 1
10	Sensor 3 value	Similar to Sensor 1
11	Sensor 4 value	Similar to Sensor 1
12	Sensor 5 value	Similar to Sensor 1
13	Sensor 6 value	Similar to Sensor 1
14	Sensor 7 value	Similar to Sensor 1
15	Sensor 8 value	Similar to Sensor 1

Table 10-8 Fields in the csv logging file

REMARK It is recommended to log data in CoG value or CoG wavelength format and perform the conversion to another unit during the postponed analysis for best results when logging using the GOS. The conversion characteristics can differ slightly from fibre to fibre. Refer to the calibration data sheet of the fibre for details which conversion to use.

10.5 GTR Operator Software conversion routines

The conversion routines currently implemented in the GTR Operator Software are currently not the same as those described in section Appendix B. See Appendix B for more information about the origin of the conversion routines presented below. The conversions implemented are:

CoG conversion	Conversion formula from CoG value
Wavelength [nm]	$\lambda_{CoG} = 1514 + \frac{CoG_{value}}{2^{18} \cdot (1586 - 1514)}$
(Delta) Micro-strain [με]	$\mu\varepsilon = \frac{\lambda_{CoG} - \lambda_0}{\lambda_0} \cdot \frac{1}{(1 - 0.22)} \cdot 10^6$ λ_0 can be specified in the profile or set using the "Zero λ_0" button in the plot group, to store current λ_{CoG} values to λ_0. For λ_0 of 1550 nm, the conversion factor is about 1,2 pm/με.
(Delta) Temperature [°C]	As seen in ▯ the wavelength shift due to index change is 10 times stronger than the change due to expansion. For coated and/or embedded fibres, the CTE (coefficient of thermal expansion) can have a dominant strain effect on the temperature wavelength response, and user calibration is typically needed. The GOS uses the following routine to calculate the temperature: $T = \mu\varepsilon \cdot T_{conv} + T_{offset}$ T_{conv} is specified in the profile for a silica fibre, these typical default values are used in the software approximately 1.2 pm/με approximately 10.5 pm/K 10.5/1.2 ≈ 8.8 K/με T_{offset} is specified in the profile (default value 0)

Table 10-9 Conversion routines as used in the GTR Operator Software

10.6 Using GTR Operator Software

This section describes how the GOS should be used for basic user interaction. See section 10.2 for a screenshot of the GOS main screen.

10.6.1 Changing plot properties

The plot properties are the properties are depicted in Figure 10-5. Details on the settings are given in the subsections.

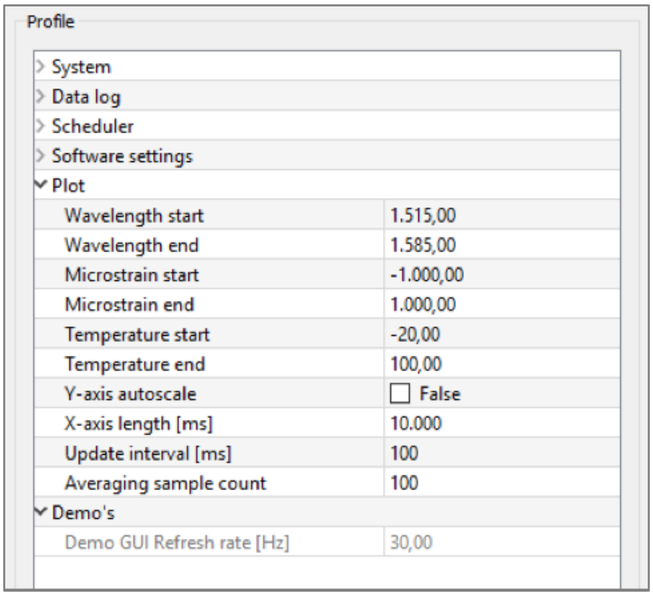


Figure 10-5 Overview of the plot section of the profile pane

10.6.1.1 Changing the scale: zooming in

Keeping the left mouse button pressed, drag the mouse over the area to zoom in on. The selected area is indicated with a rectangle in the plot.

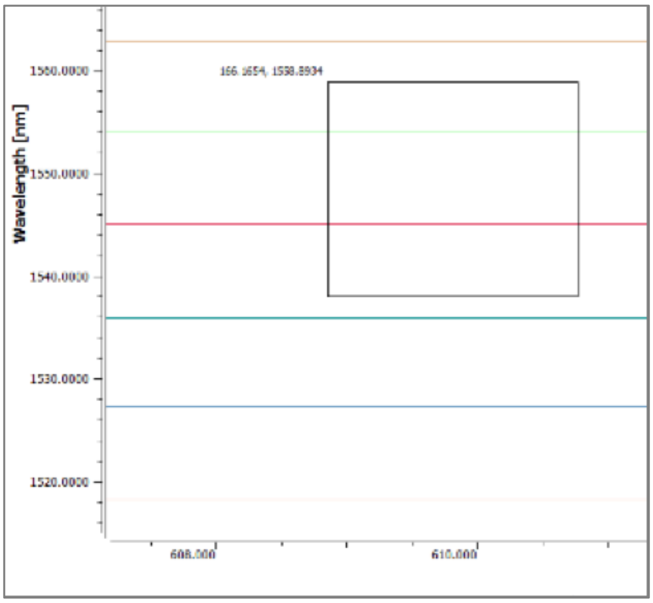


Figure 10-6 Example of the screen when zooming in

10.6.1.2 Changing the scale: zooming out

It is only possible to zoom out to the default 100% plot view. To zoom out, press the right mouse button.

10.6.1.3 Setting the plot units

In the **Plot Y-axis** pull-down menu several units for the plot view can be selected (see section 10.6.1).

- Wavelength [nm]:
  - The CoG value converted to CoG wavelength value
- Microstrain [με]:
  - The CoG wavelength value converted to microstrain
- Temperature [°C] :
  - The CoG wavelength value converted to temperature
- CoG [Centre of Gravity]:
  - The CoG output value

Plot view units can also be selected from the **Channel Unit** function (see section 10.6.1.7)

10.6.1.4 Setting the plot Y-axis range

- Zoom in
- Manually change the start/end entries of the applicable Y-axis in the plot section of the profile (see section 10.6.1)
- Auto scale the Y-axis. Select the auto-scale option in the plot section of the profile (see section 10.6.1)

10.6.1.5 Setting the plot X-axis range

- Zoom in
- Manually change X-axis length entry of the timing in the plot section of the profile (see section 10.6.1)
- Change the X-axis refresh rate in the plot section of the profile.

10.6.1.6 Setting the resolution of the plot

Increase or decrease the number of samples per pixel in the **Averaging sample count**. Each *n* samples will create a pixel on the measurement line.

10.6.1.7 Customize the plot

Plot information can be customized through the **Channel properties** function in the **Software settings** of the **Profile Pane** (see section 10.6.2).

10.6.2 Software settings profile parameters

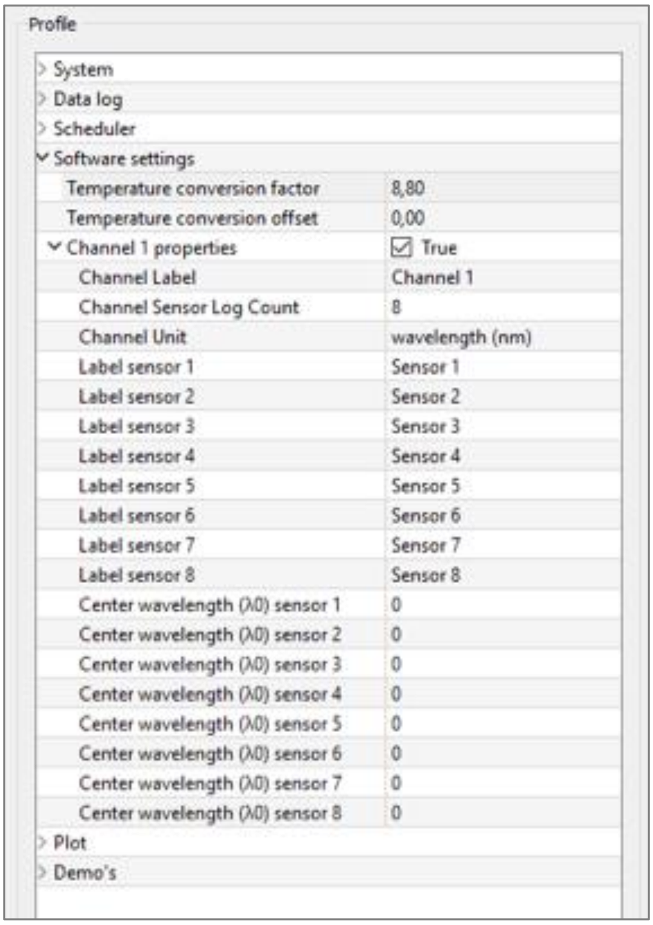


Figure 10-7 Overview of the Software settings section related to plot properties in the profile pane.

- Change the channel's name with the Channel Label function in the Channel properties.
- Disable the measured sensors by editing the Channel Sensor Log Count function.
- Change the channel's unit with the Channel Unit function. This function is an alternative for the Plot Y-axis function
- Edit Label sensor n to change the Sensor names on the bottom of the plot screen.
- Fill in the Central wavelength (λ0) sensor n to define the central wavelength of the sensor when the wavelength is not automatically obtained.

10.6.3 Data Logging

10.6.3.1 Data Log settings

In the **Data Log** section, log settings can be changed (see section 0)

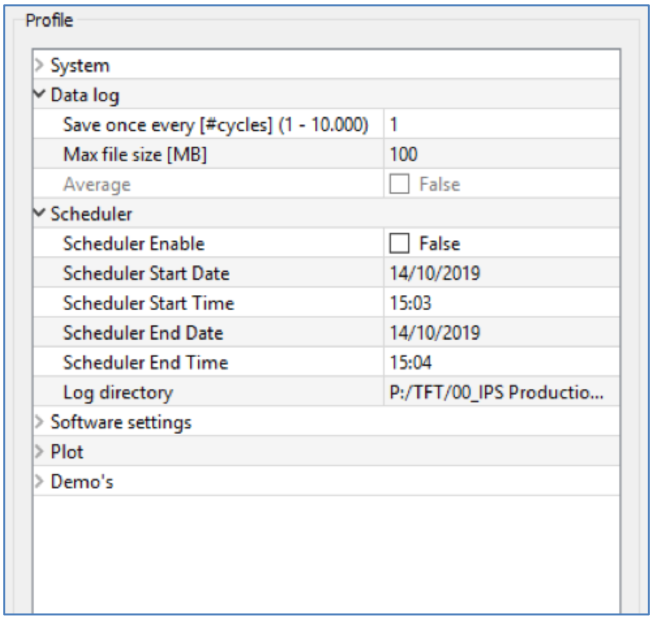


Figure 10-8 Overview of Data log and Scheduler section in the profile pane.

- Edit “Save once every [#cycles]”, reduce the size of the log file:

  The value in this field indicates the number of samples to take before a value is stored. The behaviour is dependent on the Average setting
- Change the Max file size of the log file:

  After every n MB a new file will be created in its directory.
- Average setting, (only available when “Save once every [#cycles]” not is 1)
  - If checked, the values stored will be the average value of all “Save once every [#cycles]” samples.
  - If not checked the last value of every “Save once every [#cycles]” samples will be stored.

10.6.3.2 Schedule logging

Schedule logging in the **Scheduler** section, make sure all data is filled in correctly before scheduling.

- Fill in the date in the Scheduler Starts Date when logging needs to be started. Dates should be filled in dd/mm/yyyy.
- Fill in the time in the Scheduler Start Time at which time logging needs to be started. The start time should be at least 1 minute in advance of the current time. Time should be filled in hh:mm.
- Fill in the date in the Scheduler End Date when logging needs to be ended. Dates should be filled in dd/mm/yyyy.
- Fill in the time in the Scheduler end Time at which time logging needs to be ended. The end time should be at least 1 minute in advance of the start time. Time should be filled in hh:mm.

The scheduled log is saved in a folder. Fill the complete directory of the folder in the Log directory function.

- Tick the box Schedular Enable when all data is filled in correctly. Start Logging button at the Data recording pane will lock and say Logging Scheduled, the Data log and Scheduler section will be greyed out.

10.6.4 Changing GTR settings

The firmware settings can be used to change the sensitivity and the detection level of a GTR system. Open the firmware settings screen by selecting **Firmware Settings** in the **Settings** drop-down menu. (see section 10.3)

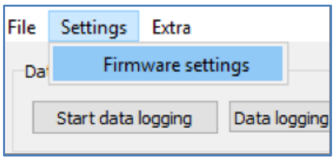


Figure 10-9 The firmware settings option can be found in settings drop-down menu.

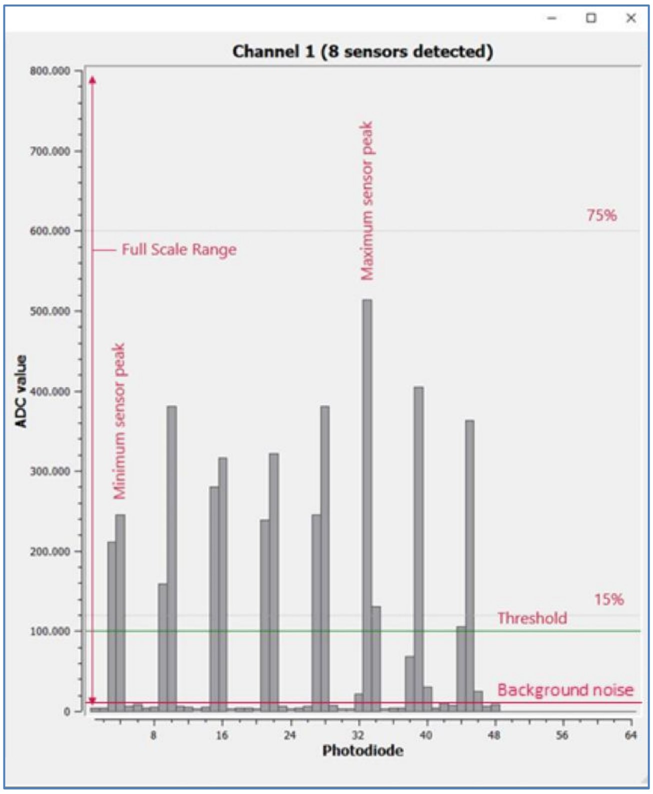


Figure 10-10 Example of the ADC Chart in the Firmware settings screen.

Option	Description
Full scale range	The full-scale range of the ADC, the possible output range of the ADC (in Digital number)
Minimum sensor peak	The lowest photo diode peak
Maximum sensor peak	The highest photo diode peak
Threshold	Threshold above which sensors are detected
15% / 75%	Range of the ADC between which the optimum measurements are taken
Background noise	Background noise filtered by threshold

Table 10-10 Legend to the ADC Chart in the firmware settings screen

10.6.4.1 Select the sensor sensitivity (F-factor)

The **Full scale (F)-factor** of a system determines the sensitivity of a system. The higher the F-factor the lower the sensitivity. Change the F-factor using the following procedure:

1. Change the value of the **Full-scale factor**
2. Click write settings

As guideline for determining a suitable F-factor the following strategy can be used:

- The minimum sensor peak is > 15% of the full-scale range (bottom dotted grey line)
- The maximum sensor peak is < 75% of the full-scale range (top dotted grey line)
- The maximum sensor peak is preferably as close as possible but below the 75% line.

When the F-factor is too high, a sensor might get saturated. When the F-factor is too low, a sensor might get below the threshold, remaining undetected. An example of saturated sensors is given in Figure 10-11. While an example of sensors below the threshold are given in Figure 10-12.

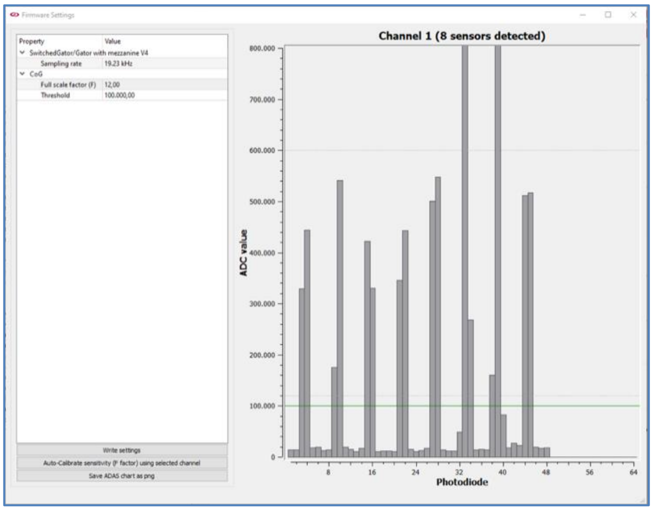


Figure 10-11 Saturated sensors can be identified by values reaching the maximum value of the plot. In this example sensors 6 and 7 are saturated.

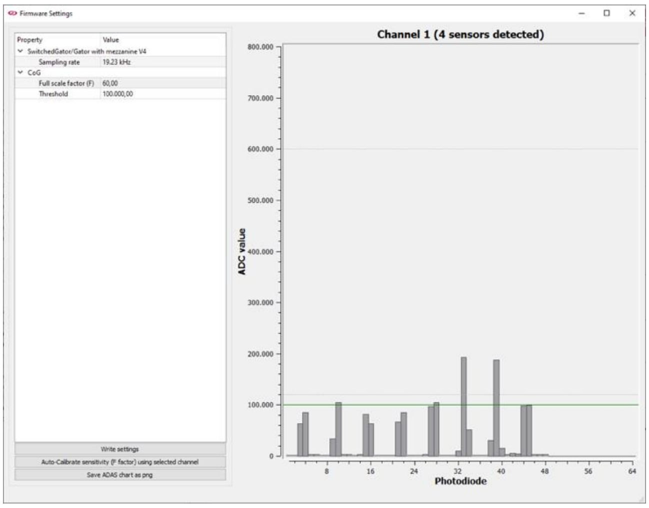


Figure 10-12 If the F-factor is too high, the signal of the sensor might become too low. In this example sensors 1, 3, 4 and 8 are not detected because they are under the threshold level of the system.

10.6.4.2 Select the detection level (CoG threshold)

The CoG threshold is used by the CoG algorithm to determine which peaks represent a sensor. Figure 10-13 shows how to determine the raw ADC value. This helps to identify the amount of background noise.

Change the CoG threshold using the following procedure:

1. Change the value of the CoG threshold value
2. Click write settings

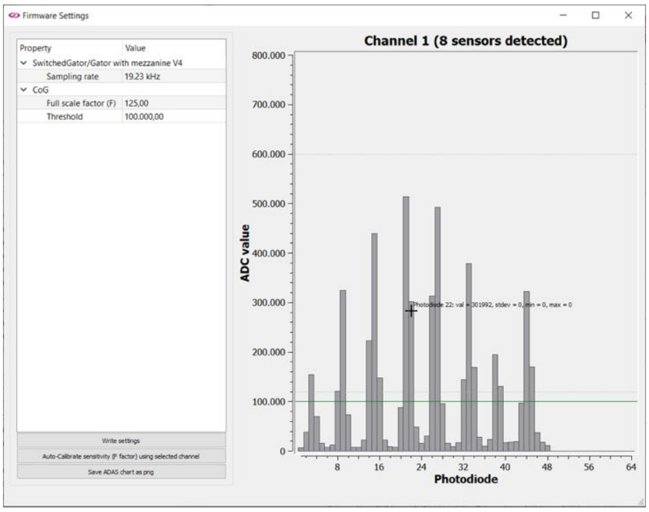


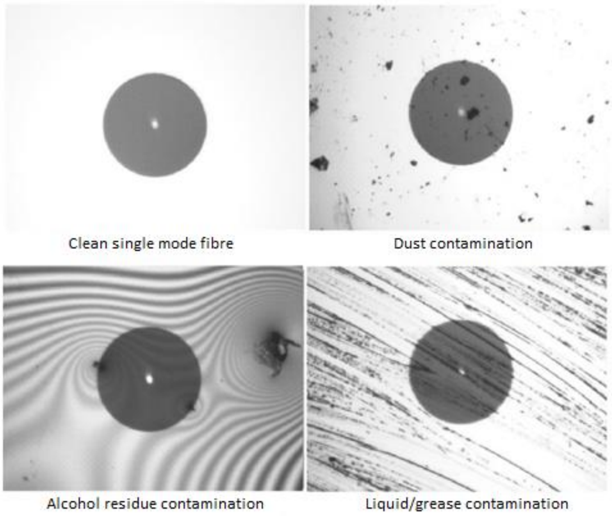
Figure 10-13 Each exact Photodiode value can be determined by hovering the mouse over the graph.

The CoG threshold setting guidelines
The threshold is at least 10% of the maximum sensor peak
The threshold value is more than twice (2x) the maximum background noise level

11 Fibre optic end-face contamination

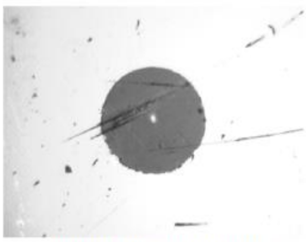
To keep your interrogator sensing properly, the fibre optic end-faces must be in clean conditions. It is essential to work with clean fibres to prevent the interrogator from getting poor sensor detections.

The images below show a clean fibre, a fibre with dust contamination, a fibre with alcohol residue and some liquid/grease contaminations.



When the fibre optic end-faces are not cleaned properly; dust, alcohol and finger grease can cause contaminations or damages i.e., cracks, scratches, or pits, that result in poor insertion losses and back reflections. A contaminated fibre optic end-face can cause cross-contamination to the other fibre optic end-face, when mating the two fibres. This contamination can cause permanent damage on both end-faces. Make sure the end-faces are inspected and clean before connecting the fibres. Always inspect the end-face again after cleaning. Store the interrogator and fibres with the provided protection cap(s). The caps are for protection against contamination and damage. The cap will not guarantee that the end-faces are kept clean, as they can attract dust. However, the dust can easily be cleaned off.

The image below shows a damaged fibre optic end-face. This end-face has scratches and pits and will result in high insertion loss or back reflection leading to sensor read-out error.

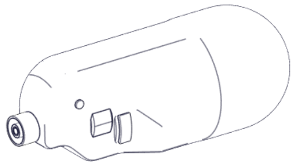
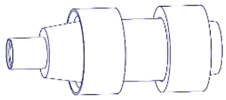
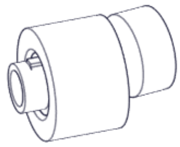
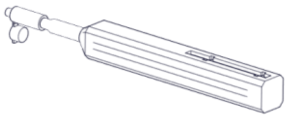


Damaged single mode end-face

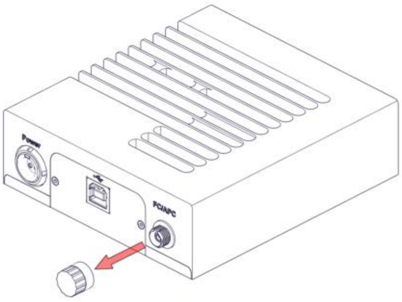
1. **Inspect both end-faces before connecting**
2. **Clean when necessary**
3. **Always re-inspect after cleaning**

12 Cleaning Instructions

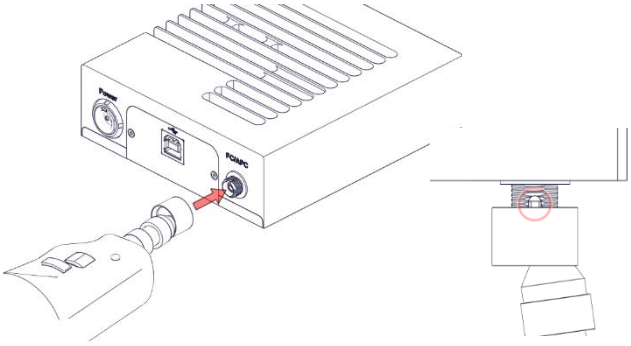
12.1 Required tooling

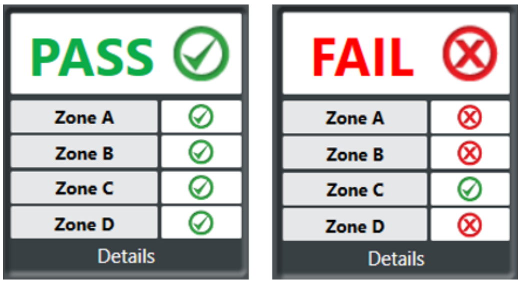
ID	Description	Picture
1	Digital fibre inspection probe (magnification 200/400x).	
2	Narrow long barrel for digital fibre inspection probe.	
3	Universal 2.5mm APC connector tip.	
4	FC/APC(NARROW KEY 2.0 MM) bulkhead tip.	
5	Cleaning pen for Ø 2.5mm ferrule.	

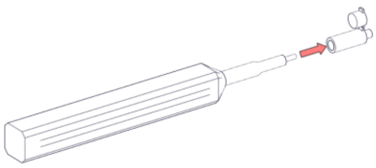
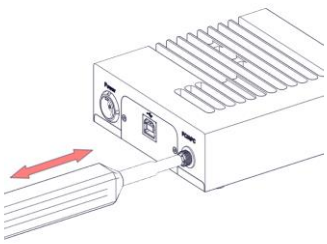
12.2 Cleaning procedure GTR1001

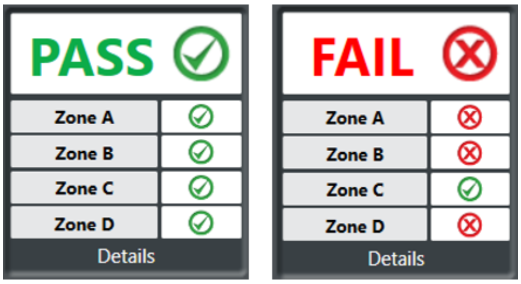
Tool	Description	Picture
1	Unscrew the cap of the fibre coupler.	

<table>
<tr><th>Tool</th><th>Description</th><th>Picture</th></tr>
<tr><td>2</td><td>Align the slot of the bulkhead tip with the fibre coupler. Insert the inspection probe in the fibre coupler, until it rests against the end of the slot.

Turn the wheel to adjust the optical end face in focus.</td><td></td></tr>
<tr><td>3</td><td>Perform a fibre inspection test if the end face is clean.

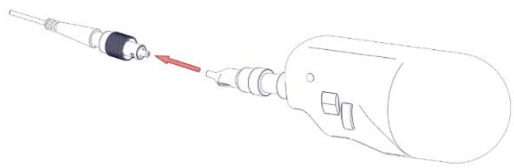
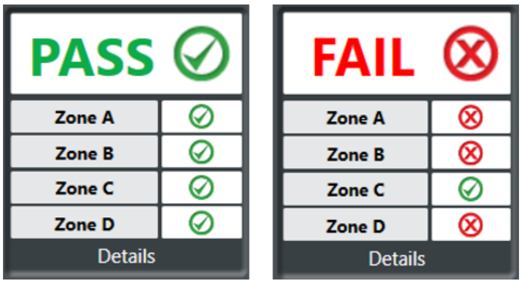
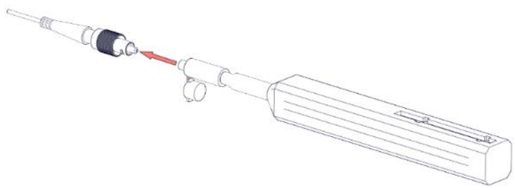
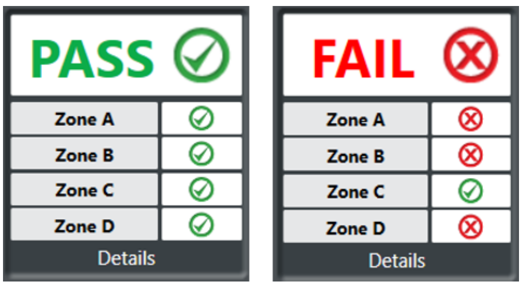
PASS = Clean, proceed to step 6.
FAIL = Proceed to step 4.</td><td>
</td></tr>
<tr><td>4</td><td>In case of a dirty end face. Use a Ø 2.5mm cleaning pen.

Pull off the adapter cap for cleaning an end face in a fibre coupler.</td><td></td></tr>
<tr><td>5</td><td>In case of a dirty end face, use the cleaning pen to clean the end face. Insert the pen into the fibre coupler and push the pen gently towards the fibre coupler till you hear a 'Click'*.</td><td></td></tr>
<tr><td>6</td><td>Run the fibre inspection test again and check if the end faces are still clean.

PASS = Clean, (process finished).
FAIL = Proceed to step 4 again.</td><td>
</td></tr>
</table>

REMARK Clicking the cleaning pen one or multiple times will not guarantee a cleaner end-face.

12.3 Cleaning procedure FC/APC(NARROW KEY 2.0 MM) connector (Fan-Out)

Tool	Description	Picture
1	Insert the ferrule into the FC/APC(NARROW KEY 2.0 MM) 2.5mm inspection tip of the inspection probe. Turn the wheel to adjust the optical end face in focus.	
2	Perform a fibre inspection test if the end face is clean. PASS = Clean (process finish). FAIL = Proceed to step 3.	
3	In case of a dirty end face use the Ø 2.5mm Cleaning pen to clean the end faces. Clean the end face by inserting the pen onto the Ø 2.5mm ferrule and push the pen gently towards the contact till you hear a 'Click'*.	
4	Run the fibre inspection test again and check if the end face is still clean. PASS = Clean (process finished). FAIL = Proceed to step 3 again.	

REMARK Clicking the cleaning pen one or multiple times will not guarantee a cleaner end-face.

13 Decommissioning

1. Make sure the device is turned off.
2. Disconnect the power connector ⑧, pull back the knurled part to release the connector.

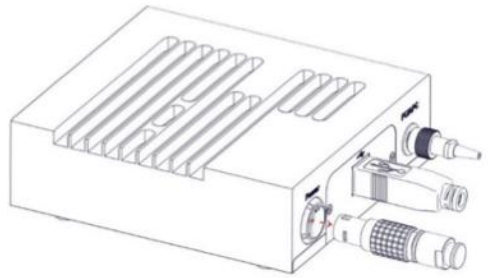


Figure 13-1 Disconnecting power connector

3. Disconnect the USB connector ⑨.

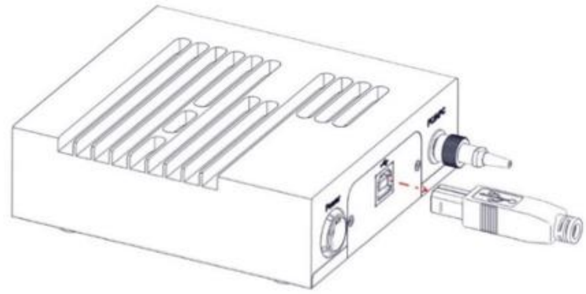


Figure 13-2 Disconnecting USB connector

4. Remove the FC/APC(NARROW KEY 2.0 MM) connector ⑩ and place the provided protective cap on the FC/APC(NARROW KEY 2.0 MM) connection ⑦.

CAUTION Do not look directly or indirectly in the fibre-optic connector. (Section 6.1)

CAUTION Remove the FC/APC(NARROW KEY 2.0 MM) connector preferably in a clean environment to prevent for dirt particles damaging the fiber connector. (Section 12)

WARNING Only use the provided protective cap to protect the FC/APC(NARROW KEY 2.0 MM) connector. Inappropriate use of protective caps can induce damage to the FC/APC(NARROW KEY 2.0 MM) connection or insufficiently cover the output light source.

Appendix A Data stream format

As soon as a GTR is switched on, sensor data is being created and transferred over the USB connection. At an interval rate determined by the GTR sampling rate; series of data sets are transferred using the following sequence of 43 bytes (Big-endian):

- Byte 00-15 contain the header
- Byte 16-18 contain GTR status information
- Byte 19-21 contain the data from sensor 1
- Byte 22-24 contain the data from sensor 2
- Byte 25-27 contain the data from sensor 3
- Byte 28-30 contain the data from sensor 4
- Byte 31-33 contain the data from sensor 5
- Byte 34-36 contain the data from sensor 6
- Byte 37-39 contain the data from sensor 7
- Byte 40-42 contain the data from sensor 8

Data stream format				
GTR packet header (16 bytes)				
GTR status (3 byte)	Sensor 1 (3 byte)	Sensor 2 (3 byte)	Sensor 3 (3 byte)	Sensor 4 (3 byte)
Sensor 5 (3 byte)	Sensor 6 (3 byte)	Sensor 7 (3 byte)	Sensor 8 (3 byte)	

A.1 GTR packet header

15	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Sync (ASCII "yoho")				Version	Type	Pkt counter	
0x79	0x6f	0x68	0x6f	0x00	0x01	MSB	LSB

7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Time stamp (us)				Payload size			
LSB	MSB	..	..	LSB			

In which:

- Sync Start indicator of a GTR data packet (fixed to “yoho”)
- Version The protocol version, currently (0x00)
- Type The type of the GTR system (0x01)
- Pkt counter Counter of the number of packets sent (looping from 0-65535)
- Time stamp Time in [μs] since the GTR started measuring (usually power up)
- Payload size Payload size in bytes (0x00 0x00 0x00 0x1B)

A.2 GTR Status

23	22	21	20	19	18	17	16
Filler					Reserved		
0	0	0	0	0	MSB		

15	14	13	12	11	10	9	8
(5 bits)		TEC OK	S8 OK	S7 OK	S6 OK	S5 OK	S4 OK
	LSB						

7	6	5	4	3	2	1	0
S3 OK	S2 OK	S1 OK	Nr sensors (4 bit) value 0-8				Filler
			MSB			LSB	1

In which:

- Filler   Bits used to ensure the packet ends at a Word boundary (8 bits multiple)
- Reserved   Present for compatibility with switched GTR output data
- TEC OK   Indicator if the TEC temperature is within the control loop *
- S1 OK   Indicator if Sensor 1 is functioning within parameters **
- S2 OK   Indicator if Sensor 2 is functioning within parameters **
- S3 OK   Indicator if Sensor 3 is functioning within parameters **
- S4 OK   Indicator if Sensor 4 is functioning within parameters **
- S5 OK   Indicator if Sensor 5 is functioning within parameters **
- S6 OK   Indicator if Sensor 6 is functioning within parameters **
- S7 OK   Indicator if Sensor 7 is functioning within parameters **
- S8 OK   Indicator if Sensor 8 is functioning within parameters **
- Nr sensors   Number of sensors detected by the GTR.***

* (1 = Yes, 0 = No)

** (1 = Yes, 0 = No or no sensor detected)

*** (0-8 = nr sensors, 0xF too many sensors detected)

A.3 Sensor Data

The sensor data from a GTR is written in three bytes (24 bits). The contents of these bytes are:

23	22	21	20	19	18	17	16
Filler					Sens Ok	CoG value	

15	14	13	12	11	10	9	8
CoG value							

7	6	5	4	3	2	1	0
CoG value							

In which:

- Filler, Bits used to ensure the packet ends at a word boundary (8 bits multiple)
- Sens Ok, Indicator if the sensor functioning within parameters (see Sn OK in GTR status)
- CoG value, CoG value for the sensor (0 = error, all 1's saturated sensor)

Appendix B Unit conversion routines

B.1 CoG to Wavelength conversion

The CoG values that are generated by the GTR are absolute, calibrated central wavelengths in the operating range of the GTR. To determine the actual wavelength λ_{CoG} in nm use the formula:

$$\lambda_{CoG} = 1514 + \frac{CoG_{value} \cdot (1586 - 1514)}{2^{18}}$$

In which:

- $\boldsymbol{\lambda_0}$ Measured Centre of Gravity wavelength in nanometre
- **1514** Lowest wavelength which can be measured by the GTR1001 (1516 nm)
- $\boldsymbol{CoG_{value}}$ CoG value from the sensor data
- $\mathbf{2^{18}}$ Output value range of the GTR1001 (18 bits value)
- **1586 – 1514** Measurement range of the GTR1001 (1516 nm until 1583 nm)

B.2 Strain conversion theorem

For strain (ε) measurements using an FBG sensor, the central wavelength of that sensor (λ_0) need to be known. The sensitivity of an FBG on strain (assuming constant temperature) can be modelled as:

$$\frac{\lambda_{CoG} - \lambda_0}{\lambda_0} = (1 - p_e) \cdot \varepsilon = k \cdot \varepsilon$$

Therefor formula for determining strain is:

$$\mu\varepsilon = \frac{\lambda_{CoG} - \lambda_0}{\lambda_0 \cdot k} \cdot 10^6$$

In which:

- $\boldsymbol{\mu\varepsilon}$ Calculated value in µstrain
- $\boldsymbol{\lambda_{CoG}}$ Wavelength value for measured CoG value in nanometre
- $\boldsymbol{\lambda_0}$ Initial central wavelength of the FBG sensor
- $\boldsymbol{p_e}$ Photo-elastic coefficient (≈0.22 for silica)
- $\boldsymbol{k}$ Strain gage factor (≈0.78 for silica)
- $\mathbf{10^6}$ Factor to convert the strain unit to µstrain

B.3 Temperature conversion theorem

For temperature measurements (T) using an FBG sensor, the calibrated temperature at the initial central wavelength of that sensor (λ_0) needs to be known. The formula for the temperature sensitivity is:

$$\frac{\lambda_{CoG} - \lambda_0}{\lambda_0} = \left(\frac{1}{n_{eff}} \frac{\delta n_{eff}}{\delta T} + \alpha \cdot k\right) \Delta T = (\zeta + \alpha \cdot k) \cdot \Delta T$$

Therefore, the formula for calculating the temperature shift ($\boldsymbol{\Delta T}$) can be written as:

$$\Delta T = \frac{\lambda_{CoG} - \lambda_0}{\lambda_0 (\zeta + \alpha \cdot k)}$$

In which:

- $\boldsymbol{\Delta T}$ Measured temperature change
- $\boldsymbol{\lambda_{CoG}}$ Wavelength value for measured CoG value in nanometre
- $\boldsymbol{\lambda_0}$ Central wavelength of the FBG sensor
- $\boldsymbol{\zeta}$ The thermo-optic coefficient ($\approx 7 \cdot 10^{-6}$ /K for silica)
- $\boldsymbol{\alpha}$ Coefficient of thermal expansion of specimen ($\approx 0.55 \cdot 10^{-6}$ /K for silica when unbonded)
- $\boldsymbol{n_{eff}}$ Effective refractive index

Appendix C Sensor array suppliers

Below approved fibre and FBG sensor suppliers are listed.

Order fibres according to the specifications of section D with one of the companies on this list to assure optimal use of the GTR1001.

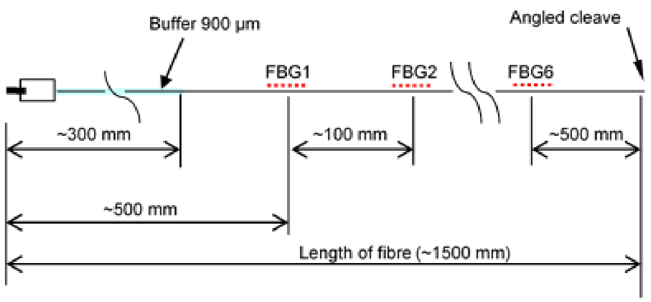
- FBGS www.fbgs.com
- Fibercore www.fibercore.com
- Atgrating www.atgrating.com
- HBM www.hbm.com
- Teraxion www.teraxion.com
- IX Blue photonics.ixblue.com
- Technica www.technicasa.com
- OFS optics www.ofsoptics.com

Appendix D Example FBG array request

The form below gives an example of what needs to be specified when ordering a sensor array:

General fibre specification	
Fibre type	smf-28e
Coating/Recoat	Acrylate/Acrylate
Buffer	Hytrel 300 mm
Fibre Length	~1500 mm
Termination 1	FC/APC(NARROW KEY 2.0 MM)
Termination 2	Angled cleave (< -20 dB)
FBGs per fibre	6
Polarization dispersion	< 5 pm
Polarization amplitude dependency	< 10%
SLSR	> 20 dB
Quantity fibres	2
RoHS (See E.2)	Yes

Fibre layout



	Central Wavelength	Bandwidth @-3dB	Peak reflectivity	Grating length	FBG centre location (measured from termination 1 facet)
FBG1	1527 nm +/- 0.5 nm	0.2 nm - 0.25 nm	> 90%	~8 mm	500 mm
FBG2	1536 nm +/- 0.5 nm	0.2 nm - 0.25 nm	> 90%	~8 mm	600 mm
FBG3	1545 nm +/- 0.5 nm	0.2 nm - 0.25 nm	> 90%	~8 mm	700 mm
FBG4	1554 nm +/- 0.5 nm	0.2 nm - 0.25 nm	> 90%	~8 mm	800 mm
FBG5	1563 nm +/- 0.5 nm	0.2 nm - 0.25 nm	> 90%	~8 mm	900 mm
FBG6	1572 nm +/- 0.5 nm	0.2 nm - 0.25 nm	> 90%	~8 mm	1000 mm
Term 2	-	-	-	-	1500 mm

Appendix E Certifications and compliance

E.1 CE Compliance

Hereby, PhotonFirst declares that the 1001-000 system is compliant with the essential requirements and other relevant provisions of the Directive 2014/30/EU (see [2]) of the European Parliament and of the Council.

CE

This equipment can be used in all countries that are member of the European Union and that are member of the European Free Trade Association.

The test reports and D.O.C. can be requested by e-mail: support@photonfirst.com.

E.2 RoHS compliance

PhotonFirst declares that the GTR1001 product is in accordance with to the RoHS Directive 2011/65/EU (see [4]), which restricts the use of hazardous substances in electrical and electronic equipment.

An RoHS compliance statement can be requested by e-mail: support@photonfirst.com.